https://indico.cern.ch/event/1255543/

WP4 : Beam instrumentation, characterization and dosimetry

GSI, 20.04.2023

Knowledge Transfer Meeting

https://indico.cern.ch/event/1255543/

HEARTS

Uli Weber / Tim Wager / C. Schuy
GSI Biophysics

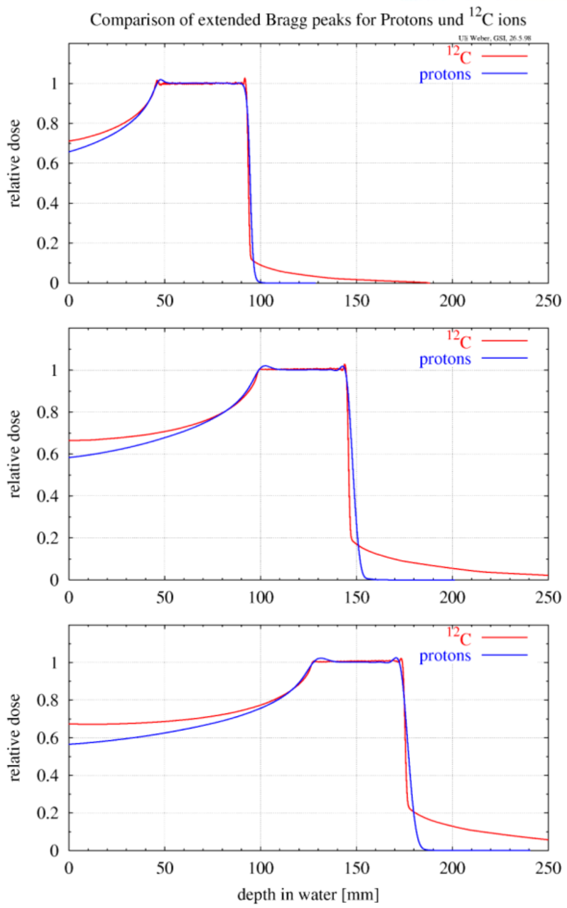
This project has received funding from the European Union’s Horizon Europe Research and Innovation programme under GA No 101082402.

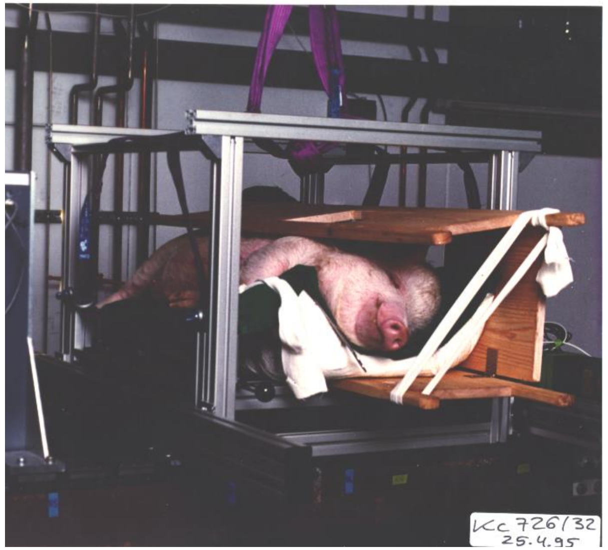
Agenda

- **09:30** → 10:00 **Welcome and Introduction**
- **10:00** → 10:30 **Definition of Terms and discussion for goals and precision**
- **10:30** → 11:00 **Raster-scanning beam application at GSI**
- **11:00** → 11:10 **Coffee brea**
- **11:10** → 11:30 **Concept for dosimetry with raster scanning at GSI**
  Including: Correction factor for HZE-particle and the MC-approach
- **11:30** → 12:30 **Existing Instrumentation for beam monitoring and dosimetry at GSI: Presentation and hands-on**
- **12:30** → 13:20 **Lunchbreal**
- **13:20** → 14:00 **Visit Cave A**
  Optionally a visit of the viewpoint for FAIR construction site
- **14:00** → 14:45 **CERN concept for dosimetry**
  - CERN beam line operation, layout and existing beam instrumentation
  - CERN diode system for dosimetry: experience with VHE ion beams, status and pla
- **14:45** → 15:00 **Coffee break**
- **15:00** → 15:30 **University Oldenburg contribution**
  - Instrumentation and ideas for dosimetry equipment at CERN
  - PTW Octavius for HEZ (high energy and Z) irradiation (content of the GSI PAC prop
- **15:30** → 16:10 **First Discussion: How to make CERN and GSI dosimetry comparable?**
  First ideas for an dosimetry benchmark experiment (which field, ions, etc.)
- **16:10** → 16:40 **Next steps**
- **16:40** → 17:00 **Closing**

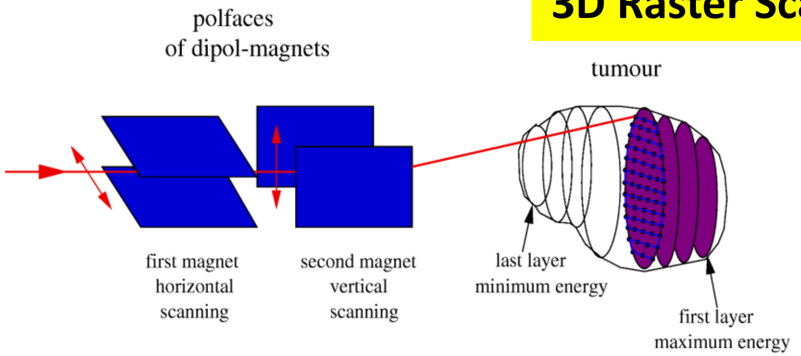
GSI Biophysics: Preparation for Carbon Ion beam therapy project (1995)

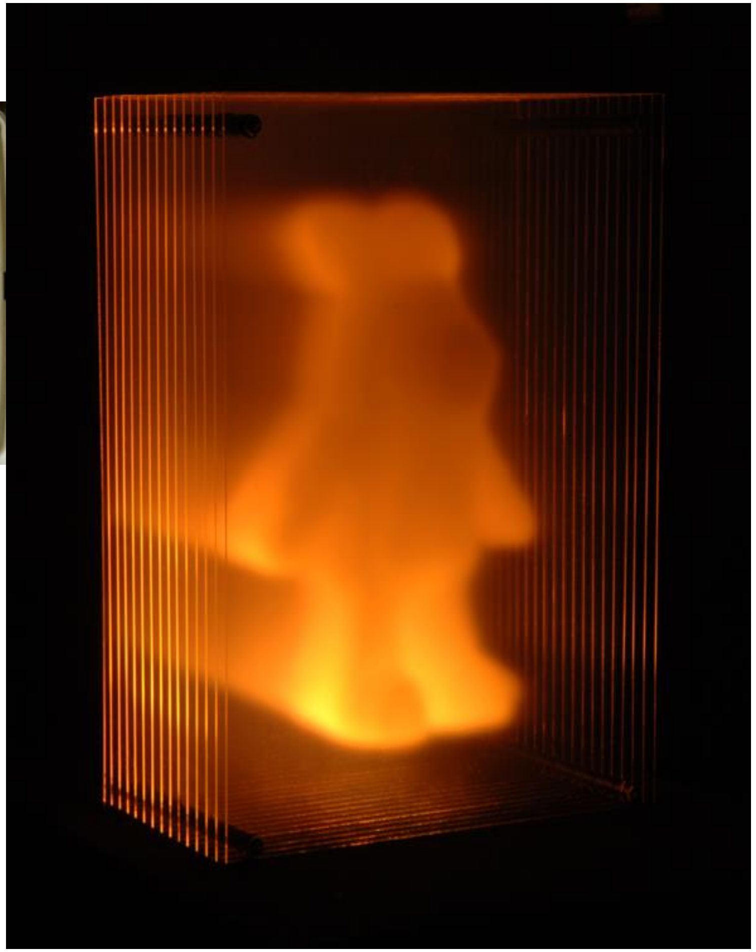
Animal experiment in Cave A, first time ‚good dosimetry‘





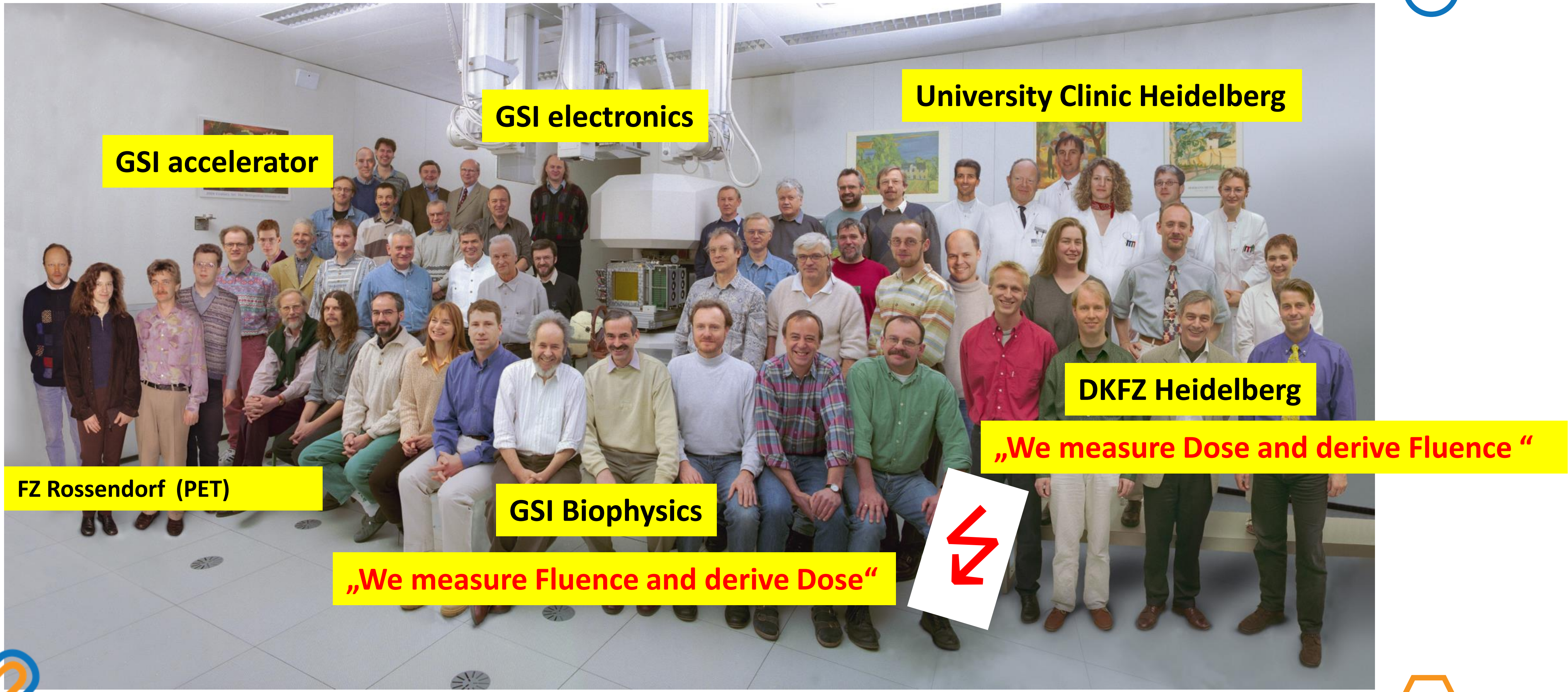
3D Raster Scanning



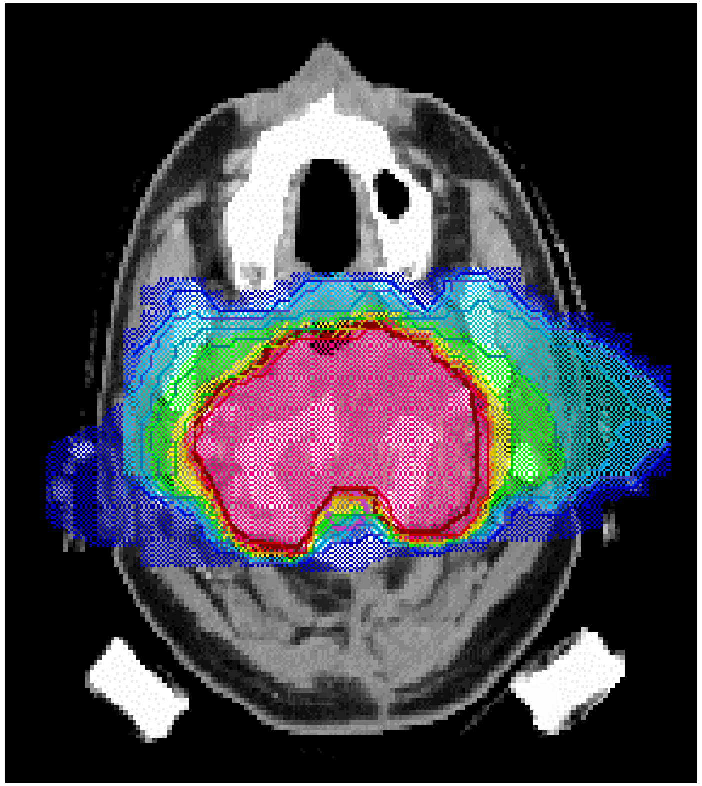


Preparation for Carbon Ion beam therapy project (1997):

A big team from GSI , Forschungsz. Rossendorf , Heidelberg University Clinic and DKFZ



GSI Biophysics: Carbon Ion beam therapy project (1997 - 2008)



- 440 patients in 11 years
- Brain tumours
- Clinically very successful

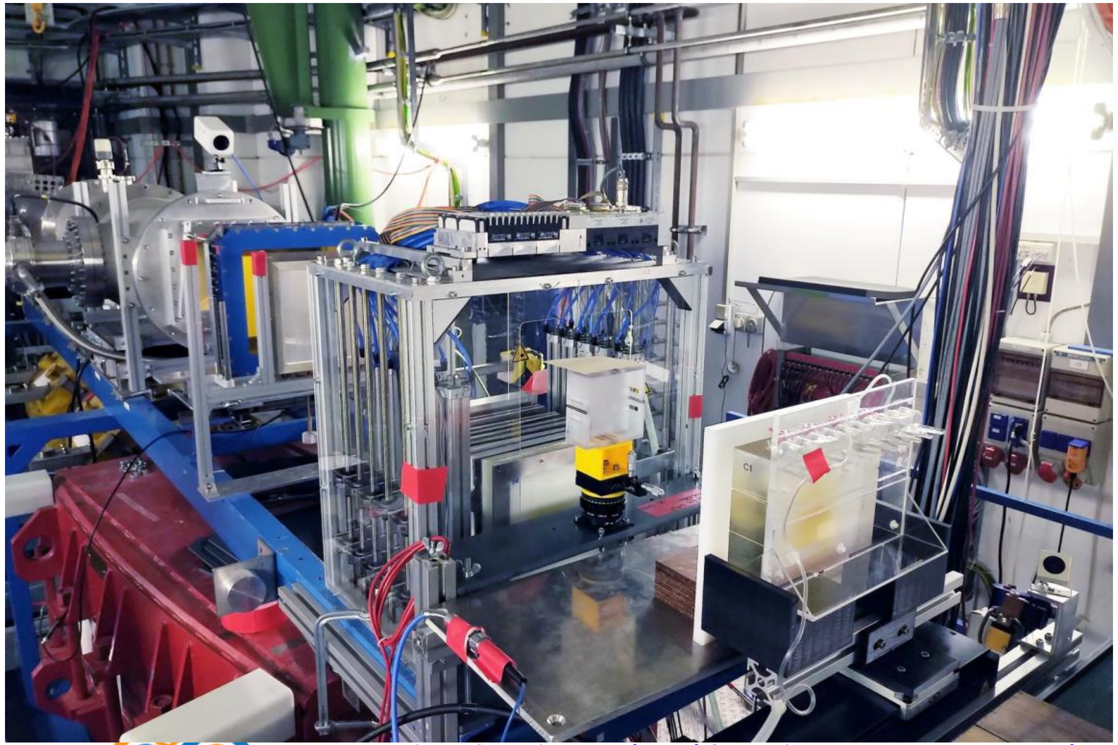
before treatment

6 Weeks after carbon tfeatment
with a dose of 60 Gye

GSI Biophysics: Long history of beam application by raster scanning, precise dosimetry and beam characterisation

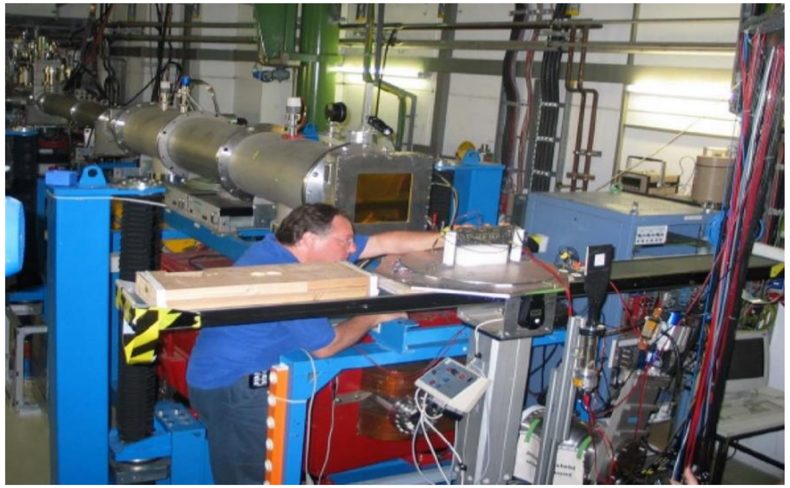
- Raster Scanning beam application
- Precise 3D dose application for ion beam therapy
- Dedicated beam monitoring detectors

➔ Good infrastructure for radio biology and radiation hardness experiments



Setup: Preclinical irradiations (mice) for carbon FLASH experiments (2023)

Setup and patient positioned on a treatment table for Carbon Ion Therapy (Photo from late 90s)



Setup:
Radiation tests for the AMS spectrometer (ISS) at GSI, CaveA

Definition of Terms and discussion for goals and precision

Dosimetry in Radio Therapy

Medical radiation dosimetry *involves measurement, calculation, and assessment of the quantity and quality of ionizing radiation exposed to and attenuated by the human body*

Accuracy: ± 3%
(not for RBE)

Absorbed dose D is a dose quantity which is the measure of the energy E deposited in matter by ionizing radiation per unit mass.

Dose : ΔE / Δm = Δ E / (ΔV ρ) **Unit :** Gy = J / kg ; ✓

Dose rate: dD / dt **Unit :** Gy/s ✓

Applicable for HEARTS

Radiation Protection (Equivalent Dose)
with weighting factors

$$H_T = \sum_R W_R \cdot D_{T,R}$$

Biologically equivalent dose (RBW) : [GyE] or [Gy biol. equ.] ;
RBE protons := 1.1 ; Carbons: typ 1.1 – 3.0

„Dosimetry“ (WP4) for Hearts

Broader Meaning: „Characterisation of the radiation field“

Absorbed dose D as defined in clinic Dose , absorbed energy E per mass

- absolute Dose : $\mathbf{D} = \Delta E / \Delta m = \Delta E / (\Delta V \ \rho)$ [Gy = J / kg] ;
- relative Dose (distribution) : $D(x,y,z) \sim D_{absolute}(x,y,z)$, but less precision in the absolute value (e.g. film measurements, Octavius)

Particles / area : Fluence Φ or F

- Fluence : Φ = ions / area [1 / cm^2] , is always a mean value (statistical hits)
- Fluence distribution : **Φ (x,y,z)** (e.g. in the pencil beam or scattered beam)
- Flux (particle flux) : **J =** ions / (area × time) [1 / (cm^2/s)]

Energy spectra

- Spectra: $dN/dE\ (Z_i, E)$; Z_i different species in a mixed field; relevant for **GCR spectrum**
- Double differential spectra: $d^2N/(dE\ d\theta)\ (Z_i, E)$; relevant for strongly scattered fields
- Lineal spectra micro dosimetry: *lineal energy y* [eV/µm] dE/dL energy (one event, *mean chord length* , random intersection)

Definition of Terms and discussion for goals and precision

„Dosimetry“ (WP4) for Hearts

Accuracy:

Dose accuracy: ± 5 % (at normal intensities)

Fluence accuracy: ± 5-10 % ? (depending on the conditions)

Fixed correlation Dose to Fluence:

$$D = \Phi \times \frac{dE}{dx} \times \frac{1}{\rho}$$

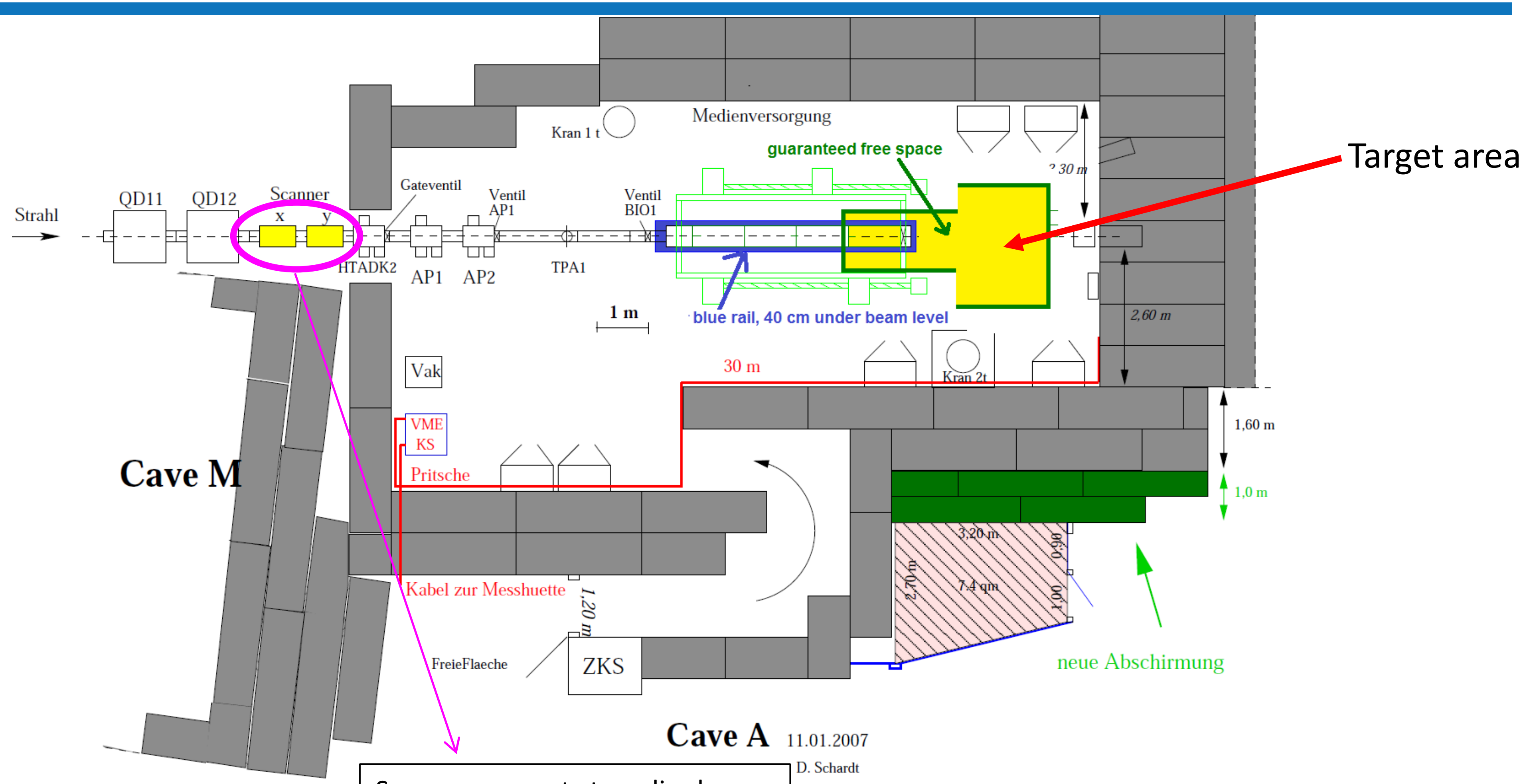
Dosis [Gy] = 1.6×10^{-10} dE/dx [MeV/cm] × Φ [$1/cm^2$] / ρ [g/cm^3]

Referenz Conditions for Dose measurement (proposal)

Reference condition	Size/ condition	
Depth of measurement	z = 0.5-1.0 cm in plastic	
Size of field	min. 8 x 8 cm^2	
Phantom	PMMA or RW3	
Homogeneitiy of lateral distribution	< 3%	
Position	Iso-centre resp. room reference point	

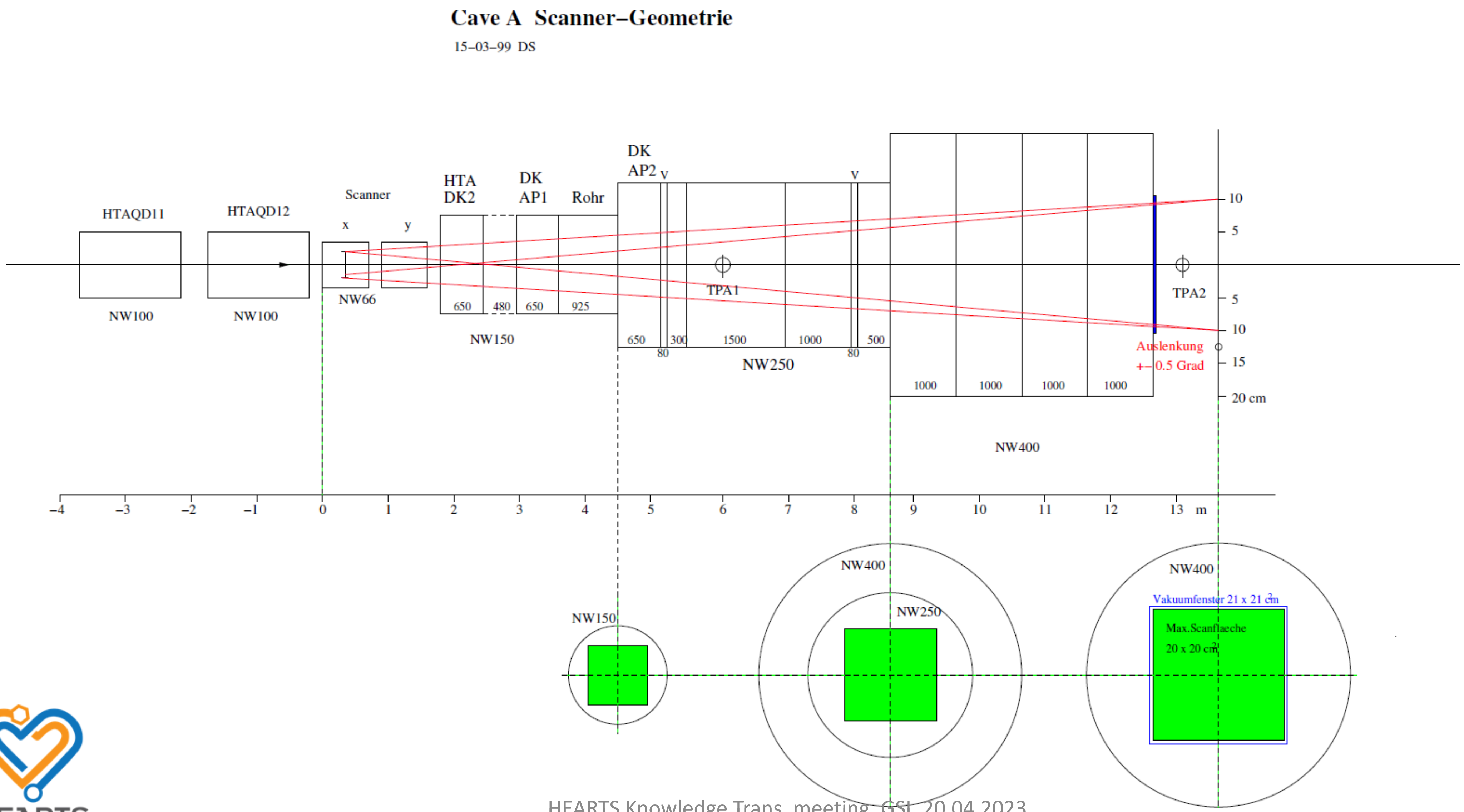
(these settings should be also used for beam monitor calibration)

Raster-scanning beam application at GSI (Cave A foot print)

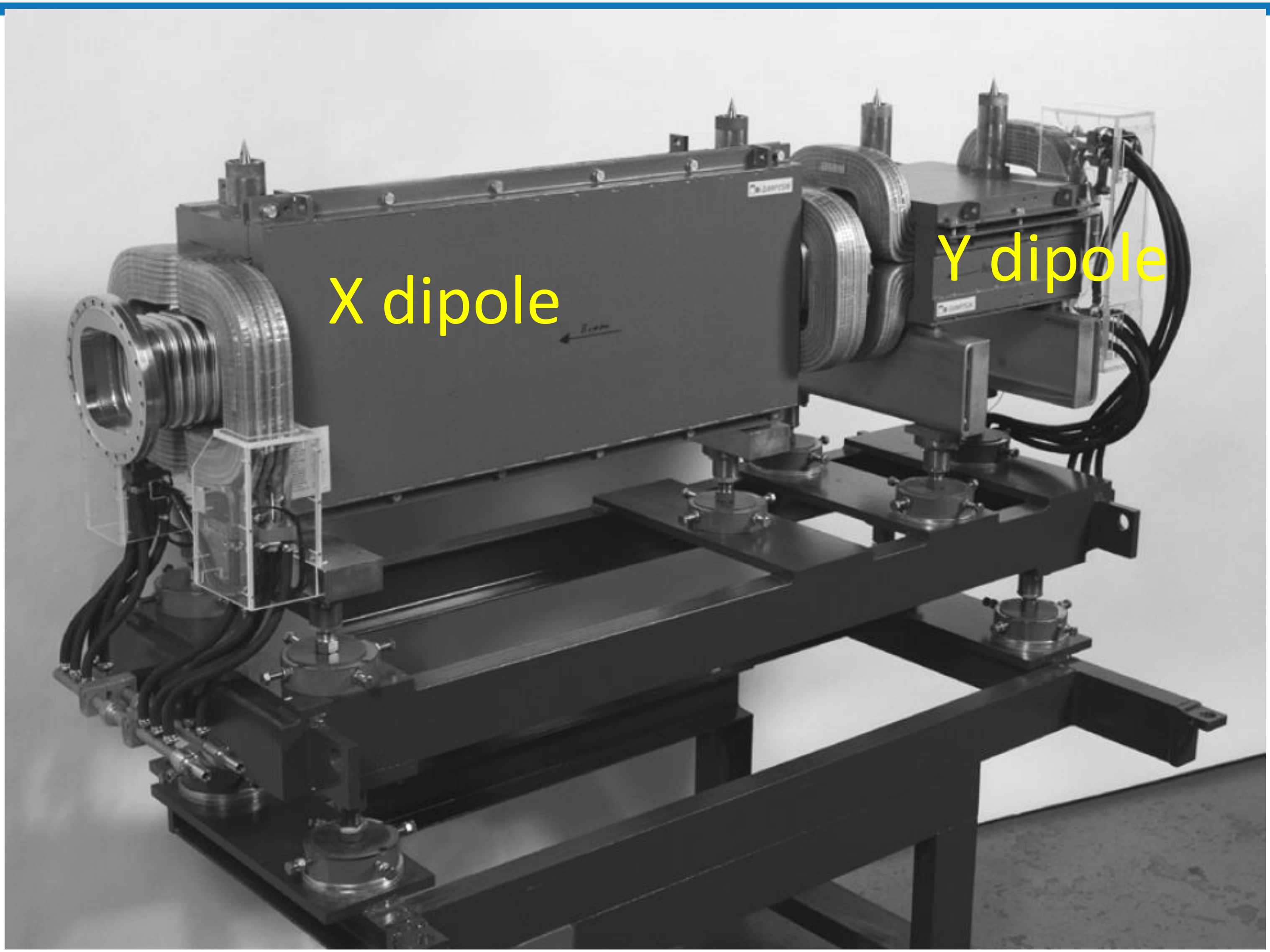


Scanner magnets two dipoles, driven by fast power supplies

Cave A Scanner Geometry



Scanner dipoles



CaveM

Scanner dipoles

Scanner parameters (2nd dipole)

Parameter		Scanner Cave A
max. deflection angle		±0.5°
nominal radius ρ	[m]	36
gap size	[mm]	70
magn. flux density B	[T]	0.50
magn. rigidity Bρ	[Tm]	18
Field ramp	[T/ms]	55
max. current	[A]	300
effective magnet length	[m]	0.314
overall length	[m]	0.550
Power supply		bipolar
DC power loss	[kW]	3.2

Typ. max scan speed : 20 m/s

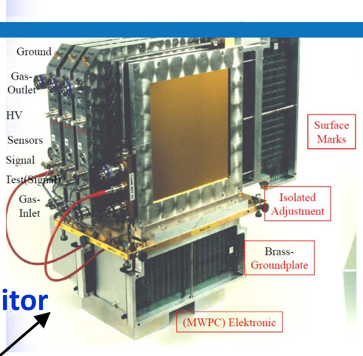
Scanning capabilities

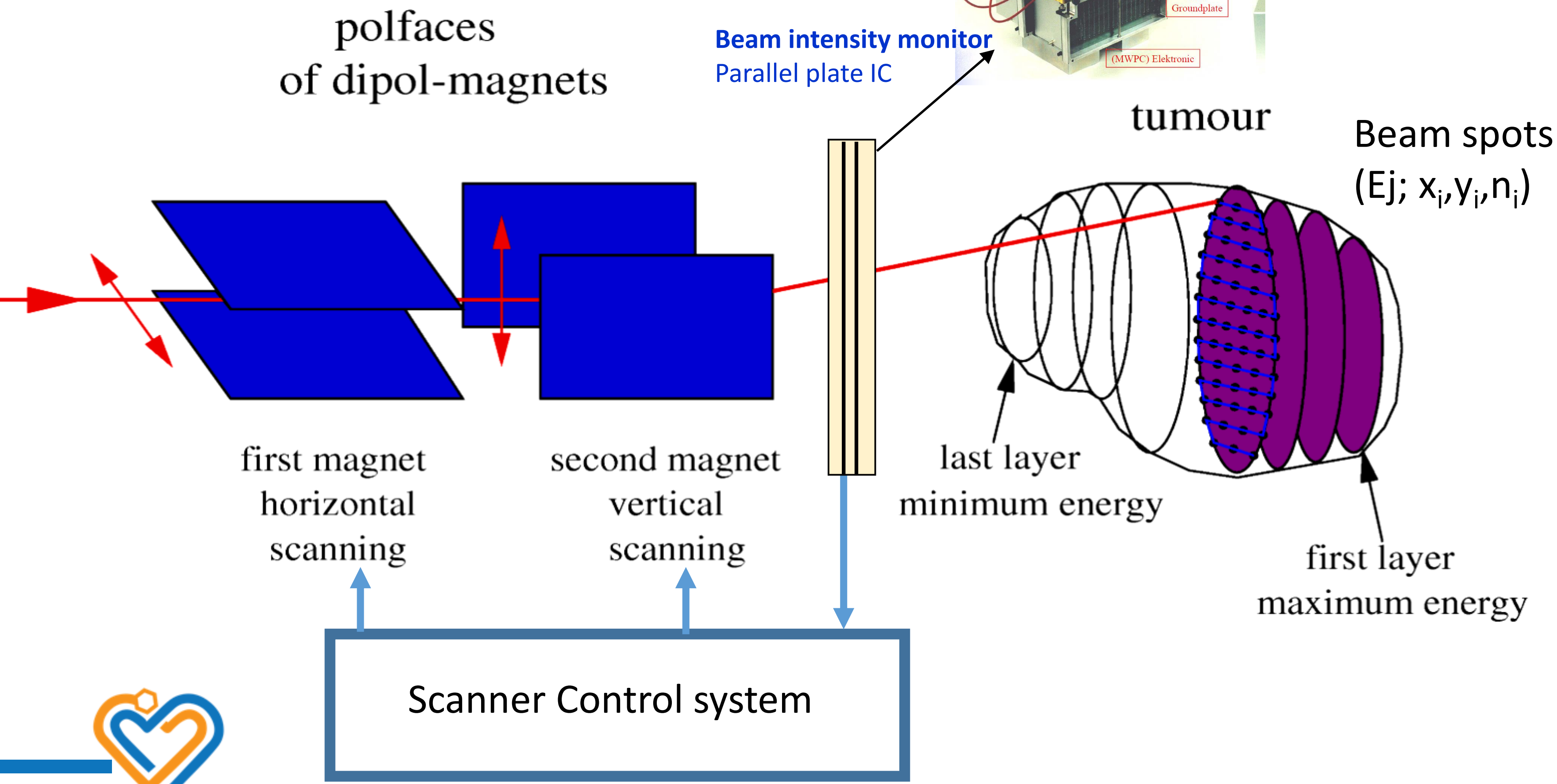
Energies	80-1000 MeV/u (2000 MeV/u)
Ions	H to U
Intensity range	500 – 10^9 per spill
Extraction	Slow 1-10 s (quadrupole resonance)
Spill length	0.2 – 10s
Spill pause	< 2s
Max scan area	Up to 20 x 20 cm^2

HEARTS

Raster-scanning beam application at GSI

Scanning principle

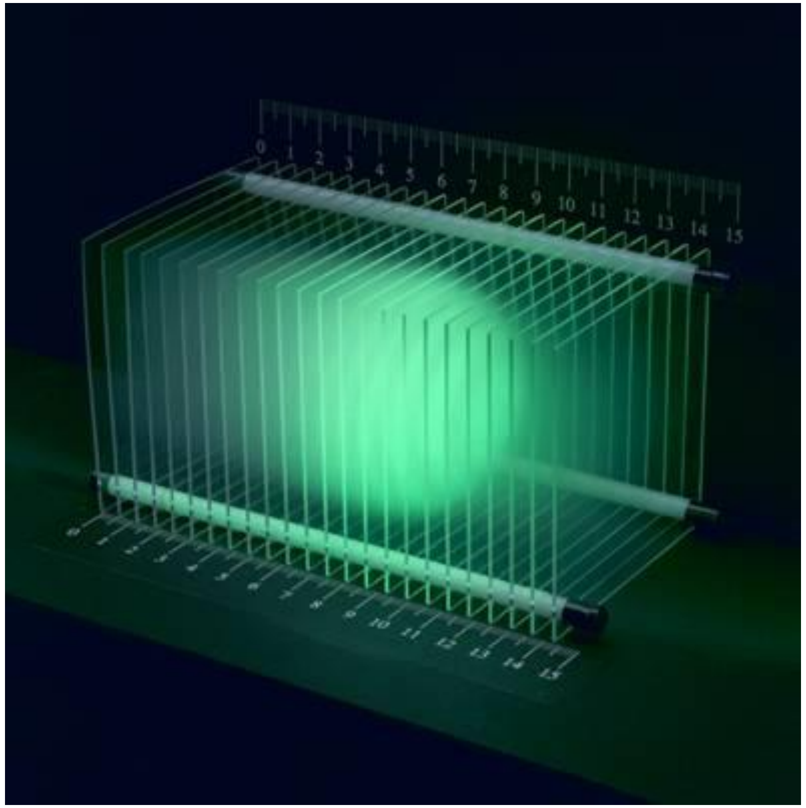


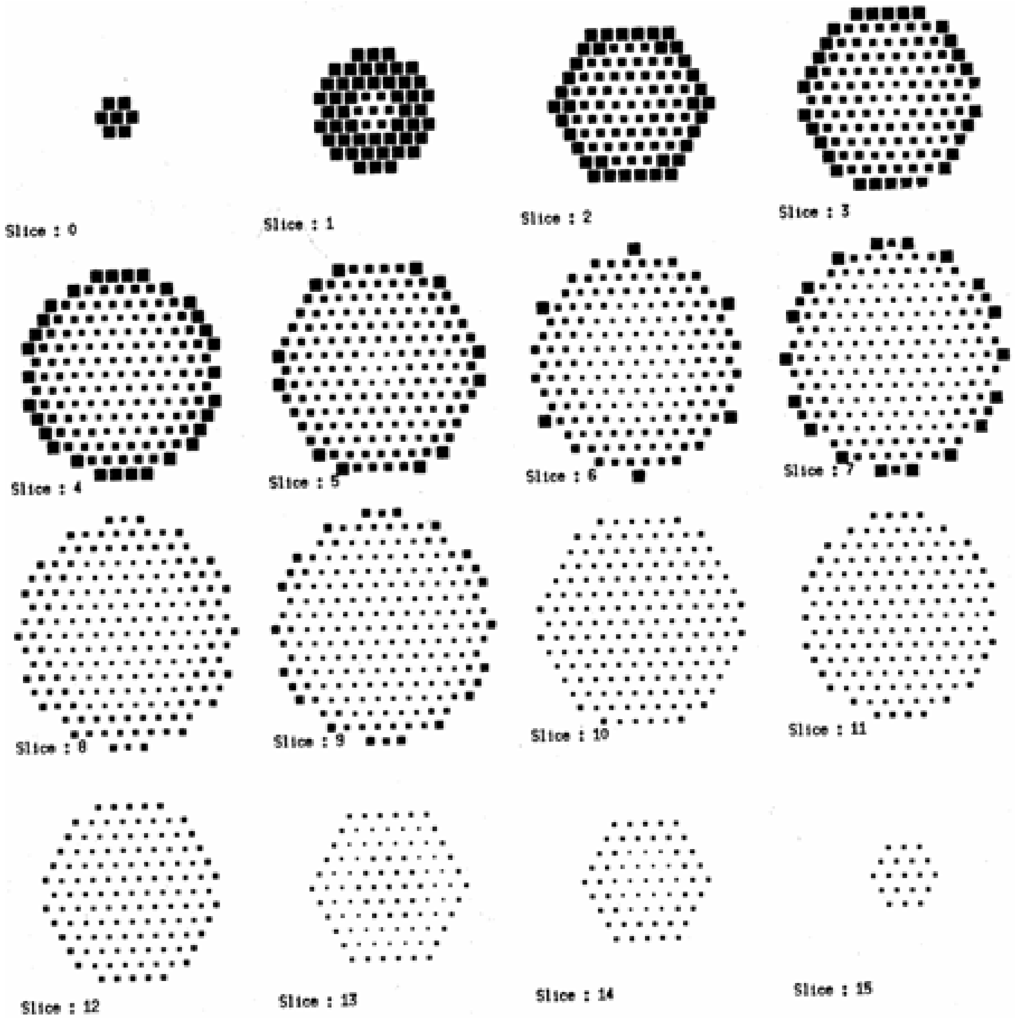


20 x 20 cm film, scanner irradiation

Raster-scanning beam application at GSI

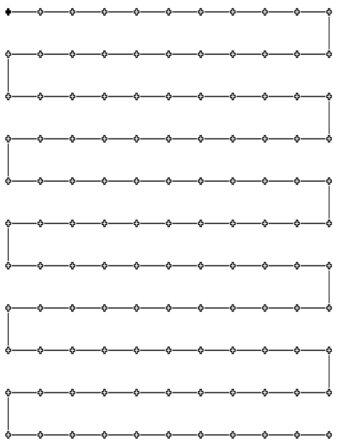
Beam spot intensities for a 3D scan, 16 energy layers





Raster-scanning beam application at GSI

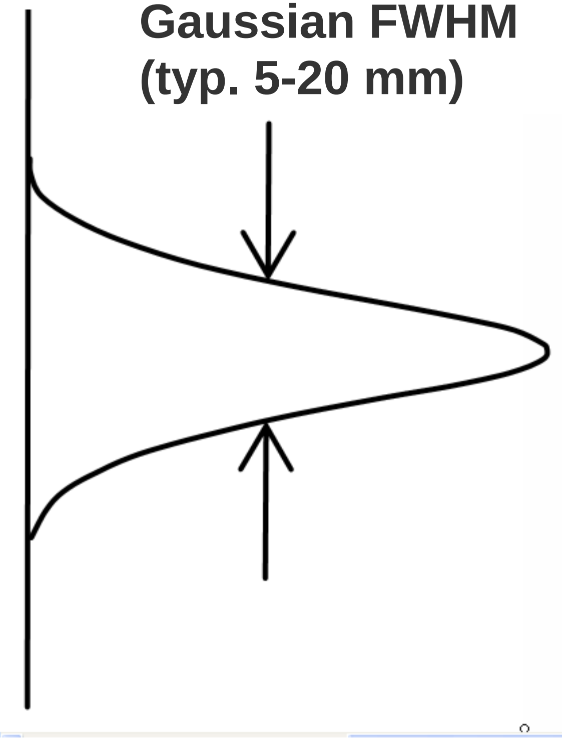
Square scan

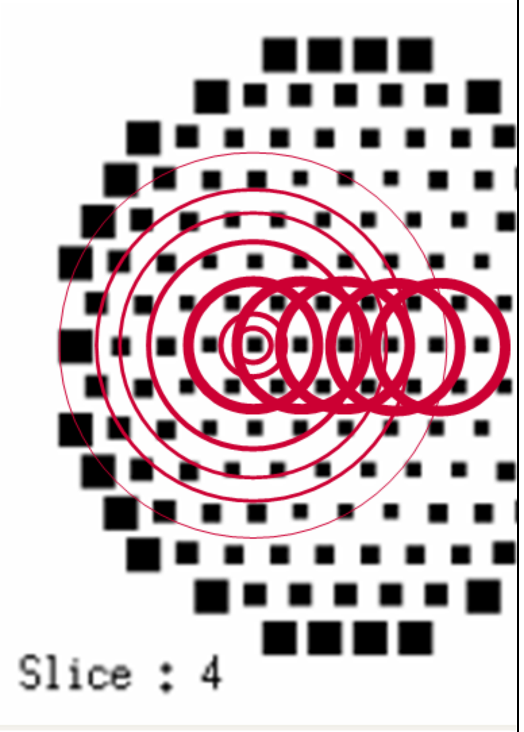


Video

Animation: Tim Wagner

Superposition of beam spots





- Beam has normally a Gaussian lateral beam profile
- The width (FWHM) of the beam must be a multiple of scan spot distance (for homogeneous flunce)

FWHM = 2.355 x σ (Sigma der Gauß-verteilung)

Irradiation plan, sphere


```
<?xml version="1.0" encoding="UTF-8"?>
<PTTxPlan>
 <Beam uid="bee035c5-03f6-4e9c-94b9-31f0fc484db1">
  <RstFormat>PT_2004</RstFormat>
  <Patient id="ICRU23_non-human_QA-ID200904221541" name="
  <TxInitiation therapist="Mr. Phantomdoctor" dateTime="2
  <TxRoom name="Room1" projectile="ION" charge="6" mass="
  <BAMS rippleFilter="3" rangeShifter="3" rangeShifterDis
  <TxTable roll="0" pitch="0" lateral="150" longitudinal=
  <Gantry angle="90"/>
  <IES number="1" energy="223.56" focus="8.500">
   <Voxel x="-10.000" y="4.000" particles="314969.0"/>
   <Voxel x="-10.000" y="2.000" particles="314969.0"/>
   <Voxel x="-10.000" y="0.000" particles="314969.0"/>
   <Voxel x="-10.000" y="-2.000" particles="314969.0"/>
   <Voxel x="-10.000" y="-4.000" particles="314969.0"/>
   <Voxel x="-8.000" y="-8.000" particles="314969.0"/>
   <Voxel x="-8.000" y="-6.000" particles="314969.0"/>
   <Voxel x="-8.000" y="-4.000" particles="314969.0"/>
   <Voxel x="-8.000" y="-2.000" particles="314969.0"/>
   <Voxel x="-8.000" y="0.000" particles="314969.0"/>
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   <Voxel x="-6.000" y="6.000" particles="314969.0"/>
   <Voxel x="-6.000" y="4.000" particles="314969.0"/>
...
...
...
   <Voxel x="-4.000" y="-8.000" particles="314969.0"/>
   <Voxel x="-4.000" y="-6.000" particles="314969.0"/>
   <Voxel x="-4.000" y="-4.000" particles="314969.0"/>

<IES number="2" energy="222.31" focus="8.500">
...
...
   <Voxel x="-10.000" y="4.000" particles="20001.5"/>
   <Voxel x="-10.000" y="2.000" particles="20001.5"/>
```
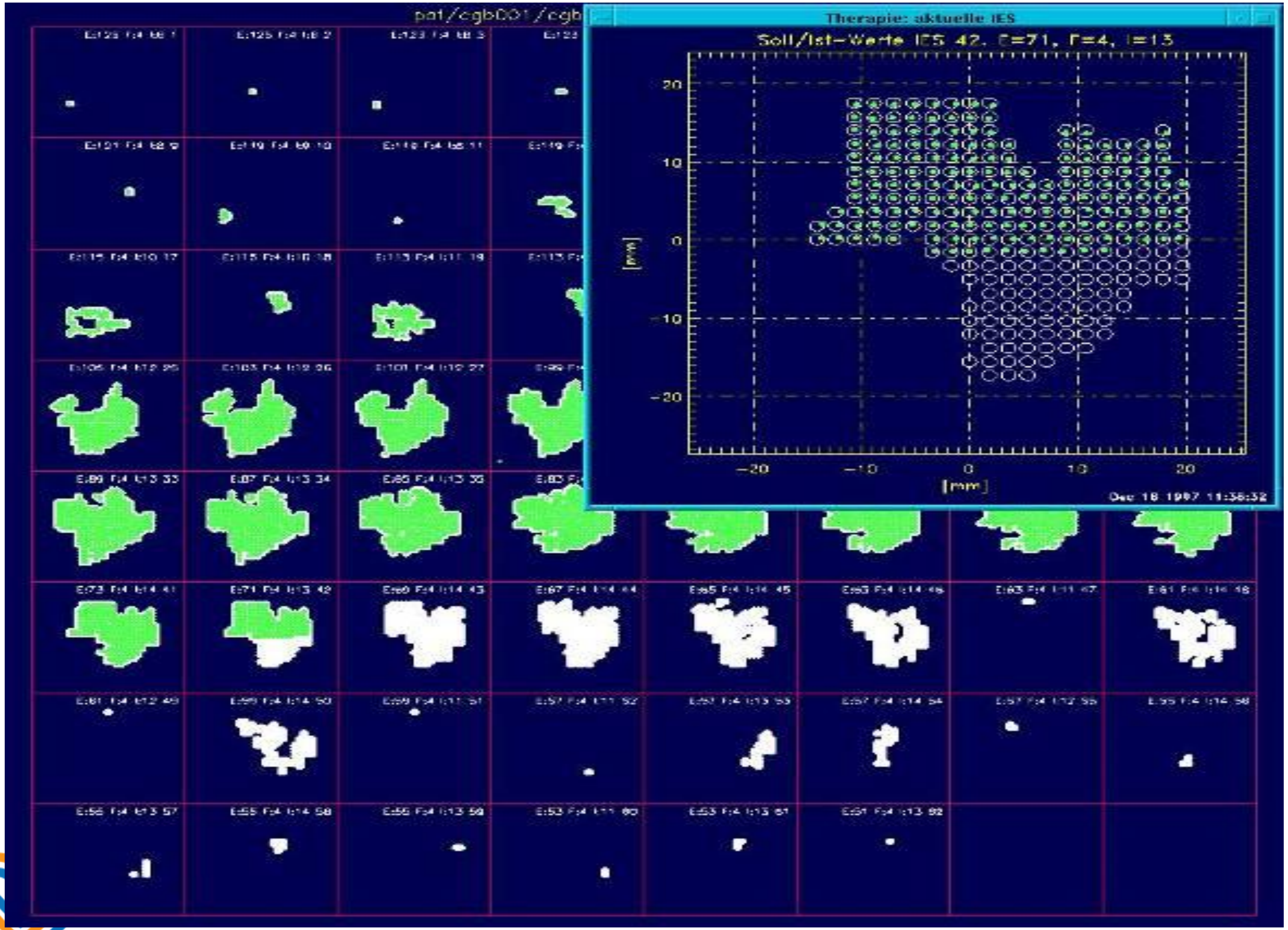

Raster-scanning beam application at GSI



Energy layers for a real toumor

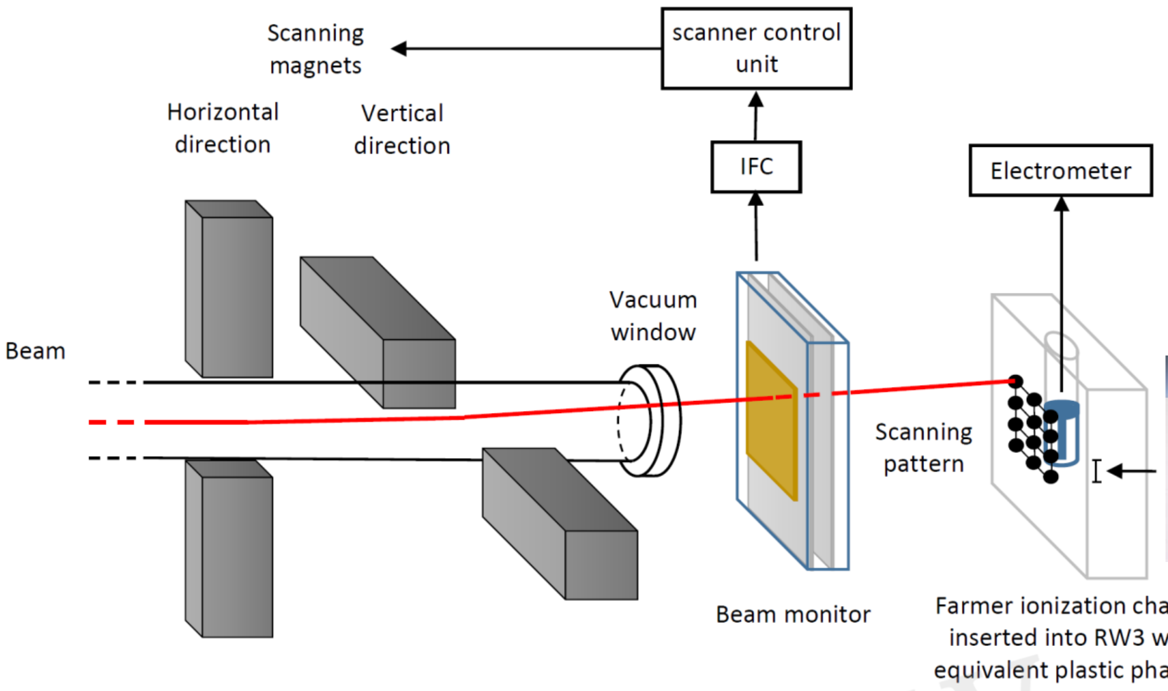
Raster-scanning beam application at GSI

Short demonstration at the
Cave-A Scanner Control System
later during the tour ….

Concept for dosimetry with raster scanning @GSI

Calibration of the beam monitors and the beam application system is performed by measuring the dose

- A homogeneous scan is applied and dose is measured at the surface
- Afterwards the calibration factors were rescaled for the right dose



PTW30013 Farmer chamber

frontiers

Beam monitor calibration for radiobiological experiments with scanned high energy heavy ion beams at FAIR

Francesca Luoni[1, 2], Uli Weber[1*], Daria Boscolo[1], Marco Durante[1, 2], Claire-Anne Reidel[1, 3], Christoph Schuy[1], Klemens Zink[4, 5], Felix Horst[1, 4]

[1]GSI Helmholtz Center for Heavy Ion Research, Germany, [2]Festkörper-Physik, Department of Physics,

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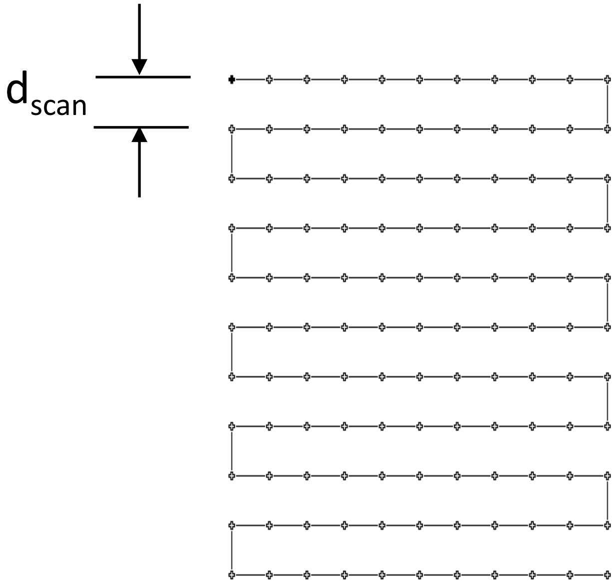
Volume 8 - 2020 | https://doi.org/10.3389/fphy.2020.568145

Concept for dosimetry with raster scanning @GSI

$$\Phi = \frac{N}{d_{scan}^2}$$

N : Ions per beam spot
Φ : Fluence

Square scan



Video

also „dE/dx“

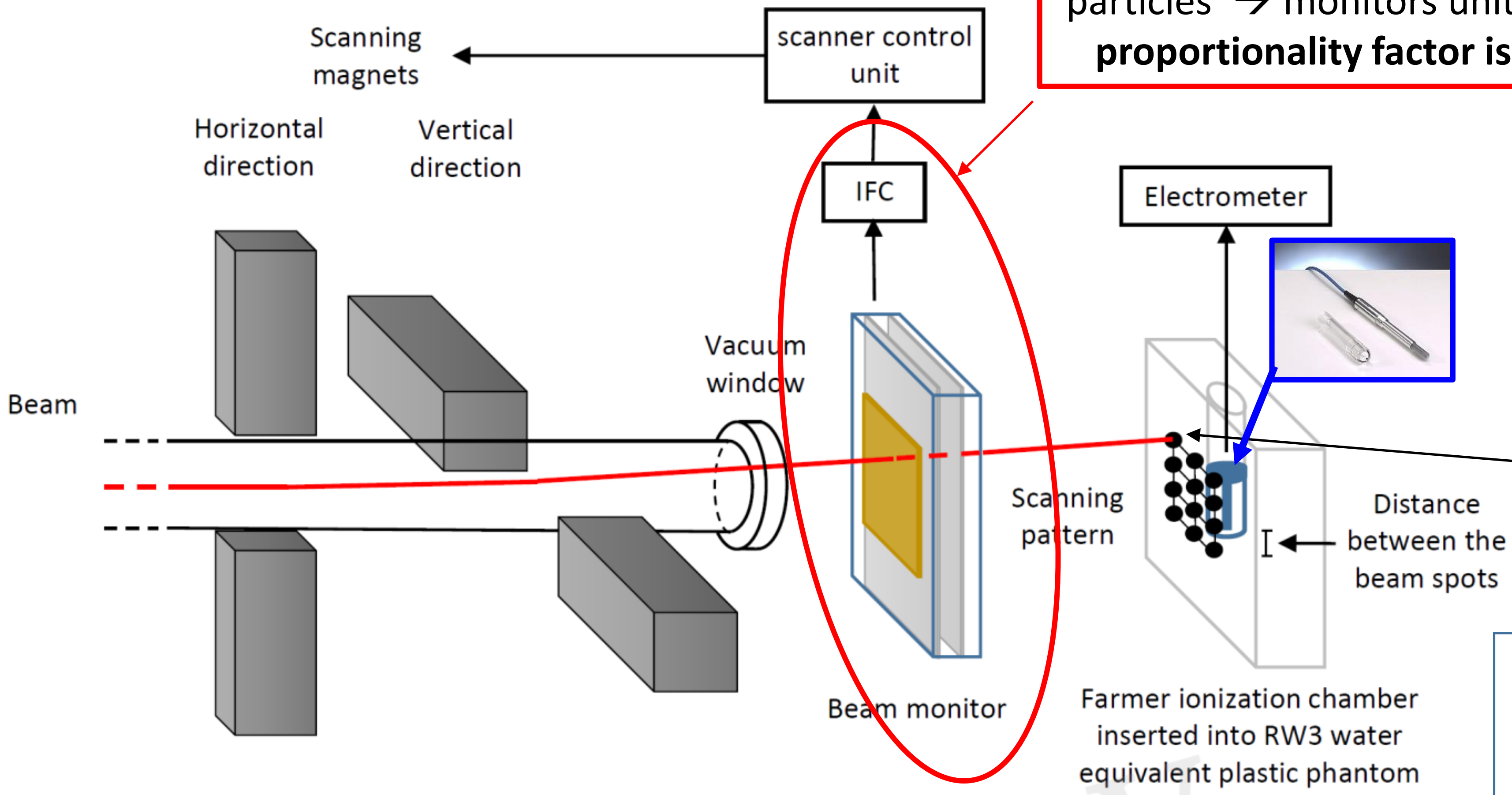
$$D_w = \Phi \cdot \frac{LET_w}{\rho_w} = \frac{N}{d_{scan}^2} \cdot \frac{LET_w}{\rho_w}$$

$$D_w = f_e \frac{n}{d_{scan}^2} \cdot \frac{LET_w}{\rho_w}$$

n : monitor units per beam spot
f_e : particles per monitor units

Concept for dosimetry with raster scanning @GSI

Beam monitor and IFC
converts
particles → monitors units (pulses)
proportionality factor is f_e



IFC = current to frequency converter,
gives a pulse per charge unit
e.g. 1 pulse/pF
or
0.1 pulse / pF

Irradiation Plan :
n monitor units (pulses)
per beam spot

$$D_w = f_e \cdot \frac{n}{d_{scan}^2} \cdot \frac{LET_w}{\rho_w}$$

n : monitor units per beam spot
f_e : particles per monitor units

Concept for dosimetry with raster scanning @GSI

Proportionality factor f_e can be calculated:

$$f_e = \frac{F}{\frac{E}{W} \cdot e}$$

F : beam particles per monitor pulse
W: W-value mean energy expended in the gas per ion pair
E : energy loss per particle in the beam monitor

Energy [MeV/u]	330
Z of ion (eg. 18 for Ar)	82
active gap [mm]	10
E-loss (interpol.) [MeV / (mg/cm2)]	17.18
E-loss [MeV]	28.98
Charge per ion [fC]	169.22
IFC-amplification [pC/pulse]	0.10
correction faktor:	1.00
Calibration factor [particles / pulse]	0.59
Calibration factor [pulse / particles]	1.69218

Excel calculator can be provided

Concept for dosimetry with raster scanning @GSI

How to measure precisely the dose ?

- **Calibration sheet from manufacturer (Co-60)**
  ? N_{DW} [Gy/C]
- **Temperature and air pressure corrections:** $k_D = \frac{(273.2+T)p_0}{(273.2+T_0)p}$
- **Correction factor for the beam quality:**

Q : Ion beams

$$k_Q = \frac{(S_{w,air})_Q}{(S_{w,air})_{Q_0}} \cdot \frac{p_Q}{p_{Q_0}} \cdot \frac{(W_{air})_Q}{(W_{air})_{Q_0}}$$

Q_0 : Cobalt-60 photons

$S_{w,air}$: water-to-air stopping power ra
p_Q : perturbation factor of the ionizatior
W_{air} : W-value (energy per ion pair)

KALIBRIERSCHEIN
Nr. 1002299 PTW

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Kalibriergegenstand
Strahlungsdetektor

Detektor	TM30013-04584		
Detektortyp	Ionisationskammer		
Kontrollvorrichtung	T48012-0419		
Halter	48002.3.003-1058		
Hersteller	PTW-Freiburg		
Auftraggeber	GSI - Gesellschaft für Schwerionenforschung mbH Postfach 11 05 52 64220 Darmstadt	Auftragsnummer : Auftragsdatum :	AU1003243 23.06.2010

Ergebnis der Kalibrierung

Messgröße: Wasserenergiedosis (D_w)
Detektor-Kalibrierfaktor: $N_{D,w} = 5{,}380 \cdot 10^7$ Gy / C

Strahlungsqualitätskorrektur

Strahlen-Qualität	Korrekturfaktor k_Q	Unsicherheit
^{60}Co	1,000	1,1 %

for a Cobalt beam

Kontrollanzeige	$k_{p,0} = 9{,}414 \cdot 10^{-2}$ Gy/min	
Isotop / Halbwertszeit	^{90}Sr / 28,8 Jahre	
Referenzbedingungen	Strahlungsqualität:	^{60}Co
	Umgebungstemperatur:	293,2 K (20°C)
	Luftdruck:	1013,2 hPa
	Relative Luftfeuchte:	50%
	Kammerspannung/Polarität:	+ 400 V
	Sättigungseffizienz:	100 %
Kalibrierdatum	25.06.2010	
Rekalibrierintervall	2 Jahre (empfohlen)	

Freiburg, den 28.06.2010

PTW-Freiburg
Physikalisch-Technische
Werkstätten Dr. Pychlau GmbH

(Unterschrift)

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Concept for dosimetry with raster scanning @GSI

TECHNICAL REPORTS SERIES No. 398

TRS 398

Absorbed Dose Determination in External Beam Radiotherapy

An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water

Sponsored by the IAEA, WHO, PAHO and ESTRO

ESTRO

Correction factor k_Q for the beam quality:

Q : Ion beams

$$k_Q = \frac{(S_{w,air})_Q}{(S_{w,air})_{Q_0}} \cdot \frac{p_Q}{p_{Q_0}} \cdot \frac{(W_{air})_Q}{(W_{air})_{Q_0}}$$

Q_0 : Cobalt-60 photons

$S_{w,air}$: water-to-air stopping power ratio
p_Q : perturbation factor of the ionization chamber
W_{air} : W-value (energy per ion pair)

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TABLE 31. CALCULATED VALUES OF k_Q FOR PROTON BEAMS, FOR VARIOUS CYLINDRICAL AND PLANE-PARALLEL IONIZATION CHAMBERS AS A FUNCTION OF BEAM QUALITY R_{res}

Ionization chamber type[a]		Beam quality R_{res} (g/cm^2)														
		0.25	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	7.5	10	15	20	30
PTW 23323 micro	—	1.027	1.025	1.025	1.025	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.023	1.023	1.023
PTW 23331 rigid	—	1.037	1.035	1.034	1.034	1.034	1.034	1.034	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.032
PTW 23332 rigid	—	1.031	1.029	1.028	1.028	1.028	1.028	1.028	1.027	1.027	1.027	1.027	1.027	1.027	1.027	1.026
PTW 23333	—	1.033	1.031	1.031	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.029	1.029	1.029	1.029	1.028
PTW 30001/30010 Farmer	—	1.033	1.031	1.031	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.029	1.029	1.029	1.029	1.028
PTW 30002/30011 Farmer	—	1.036	1.035	1.034	1.034	1.034	1.034	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.032	1.032
PTW 30004/30012 Farmer	—	1.044	1.042	1.041	1.041	1.041	1.041	1.041	1.041	1.041	1.040	1.040	1.040	1.040	1.040	1.039
PTW 30006/30013 Farmer	—	1.033	1.032	1.031	1.031	1.031	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.029	1.029	1.029
PTW 31002 flexible	—	1.032	1.030	1.029	1.029	1.029	1.029	1.029	1.029	1.029	1.029	1.028	1.028	1.028	1.028	1.027
PTW 31003 flexible	—	1.032	1.030	1.029	1.029	1.029	1.029	1.029	1.029	1.029	1.029	1.028	1.028	1.028	1.028	1.027

k_Q factors are mainly calculated
Can be verified by calorimetric measurements (graphite or water)

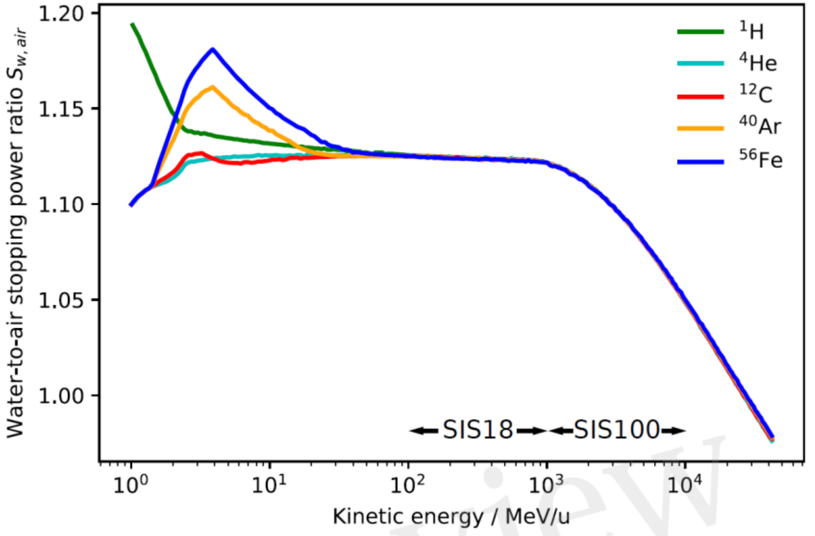
Concept for dosimetry with raster scanning @GSI

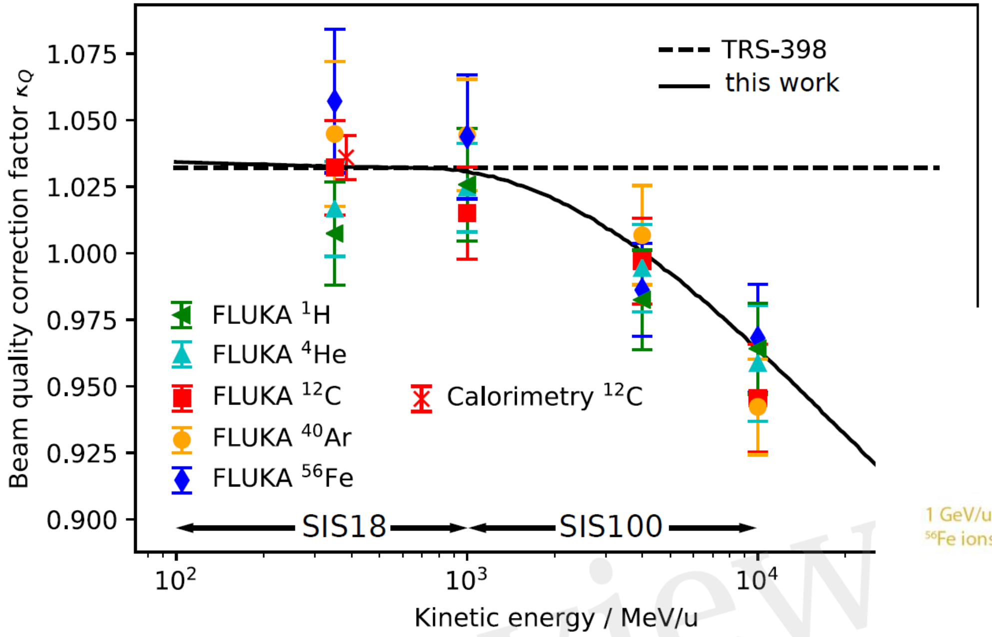
Correction factor k_Q for the beam quality:

Q : Ion beams

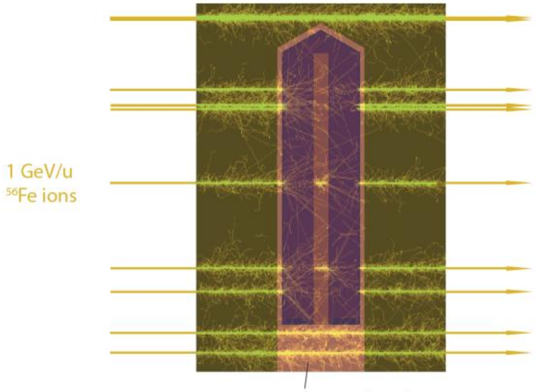
$$k_Q = \frac{(S_{w,air})_Q}{(S_{w,air})_{Q_0}} \cdot \frac{p_Q}{p_{Q_0}} \cdot \frac{(W_{air})_Q}{(W_{air})_{Q_0}}$$

Q_0 : Cobalt-60 photons





Luoni et al
Front. Phys., 29 September 2020
https://doi.org/10.3389/fphy.2020.568145



PTW 30013 Farmer chamber in water phantom

Result:

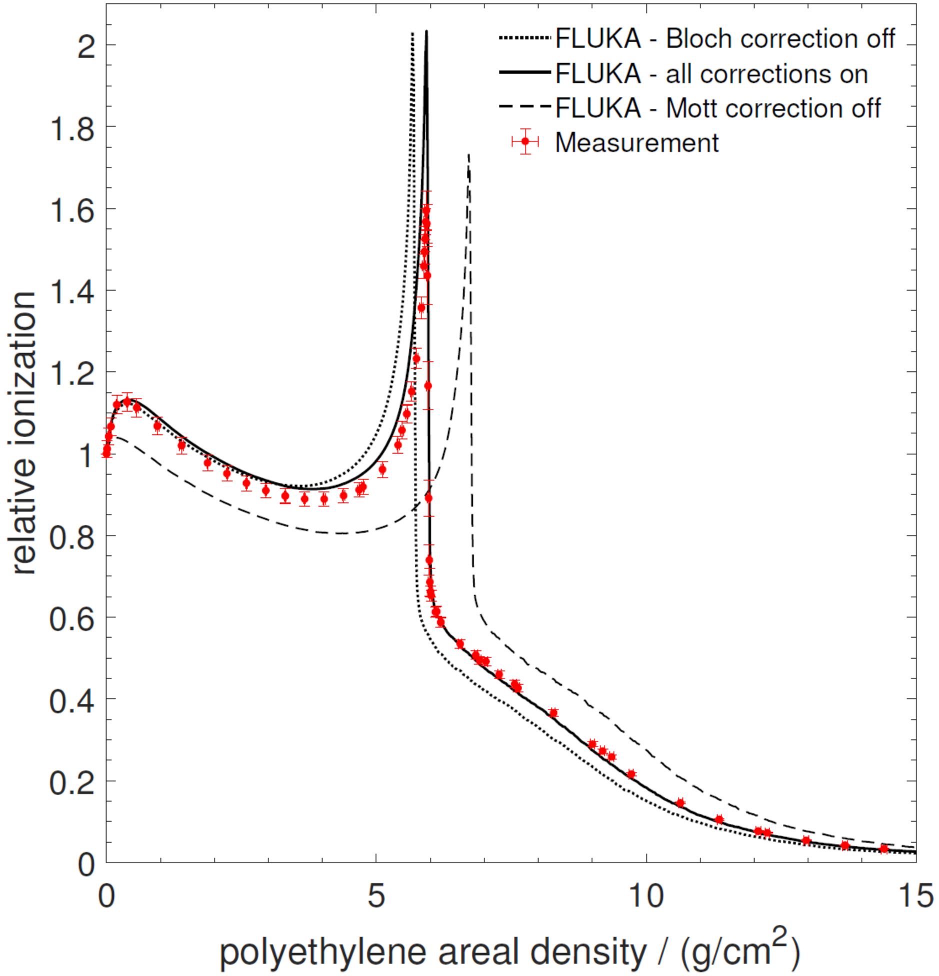
- k_Q factors from TRS-398 ok for E < 1 GeV/u
- k_Q factors to be corrected for E > 1 GeV/u (FAIR) due to relativistic effects ($S_{w,air}$)

Recommendation:

Calculation of k_Q für Pb und Uranium (- 10 GeV/u)

Concept for dosimetry with raster scanning @GSI

Uran 800 MeV/u depth dose curve



F. Horst, U. Weber et al.

Precise measurement of the Bragg curve for 800 MeV/u ^{238}U ions stopping in polyethylene and its implications for calculation of heavy ion ranges

Journal of Instrumentation, Volume 17, December 2022

DOI 10.1088/1748-0221/17/12/P12019

Existing Instrumentation for beam monitoring and dosimetry at GSI: Presentation and hands-on

Dose measurements chambers

PTW TM30013 Farmer chamber
(working horse for monitor calibration)

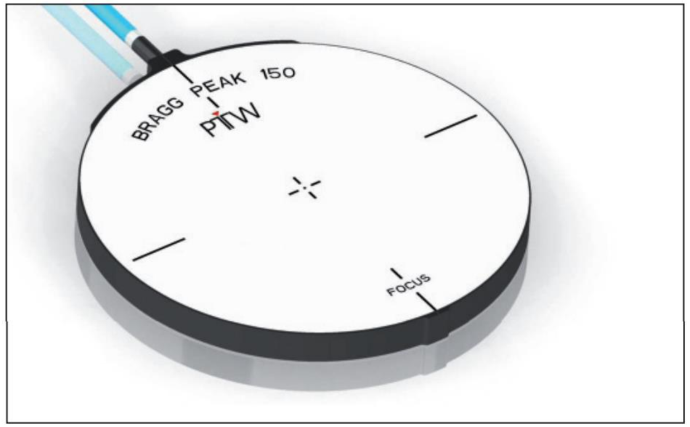
PTW M31009 Farmer chamber (pin point)

PTW Octavius
Multi ionisation chmaber Array
1500 XDR and 1600 XDR

having 1500 resp 1600
single ionisation chambers

Time resolution! 10 Hz

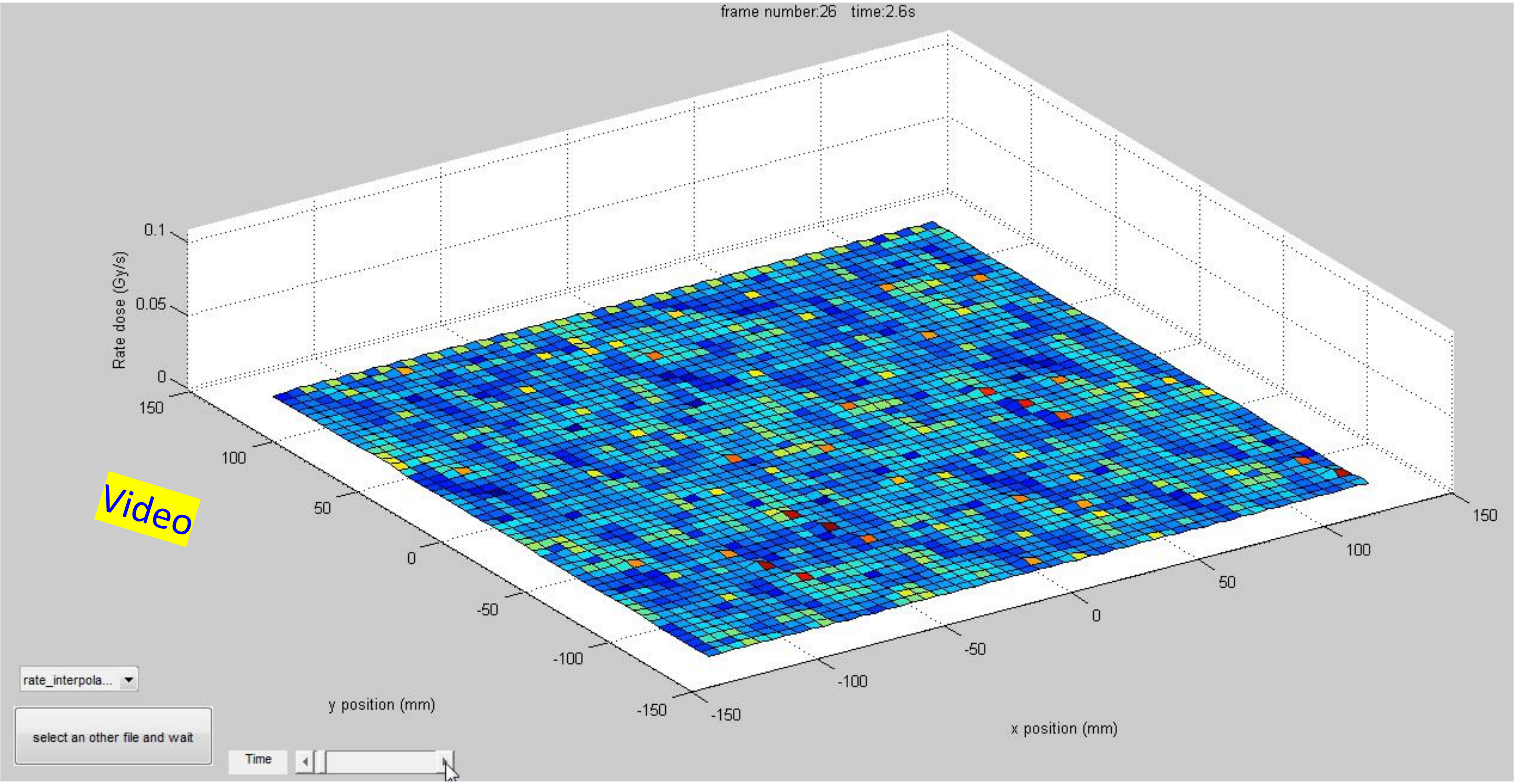
Bragg peak chamber Bragg Peak 150 Type 34089



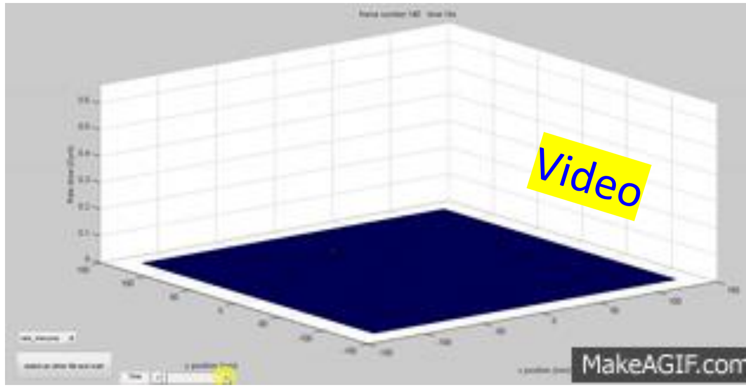
Electrometer for read out

PTW Octavius 1500 XDR in Movie mode

Shifted square field at Electron Linac Varian TrueBeam



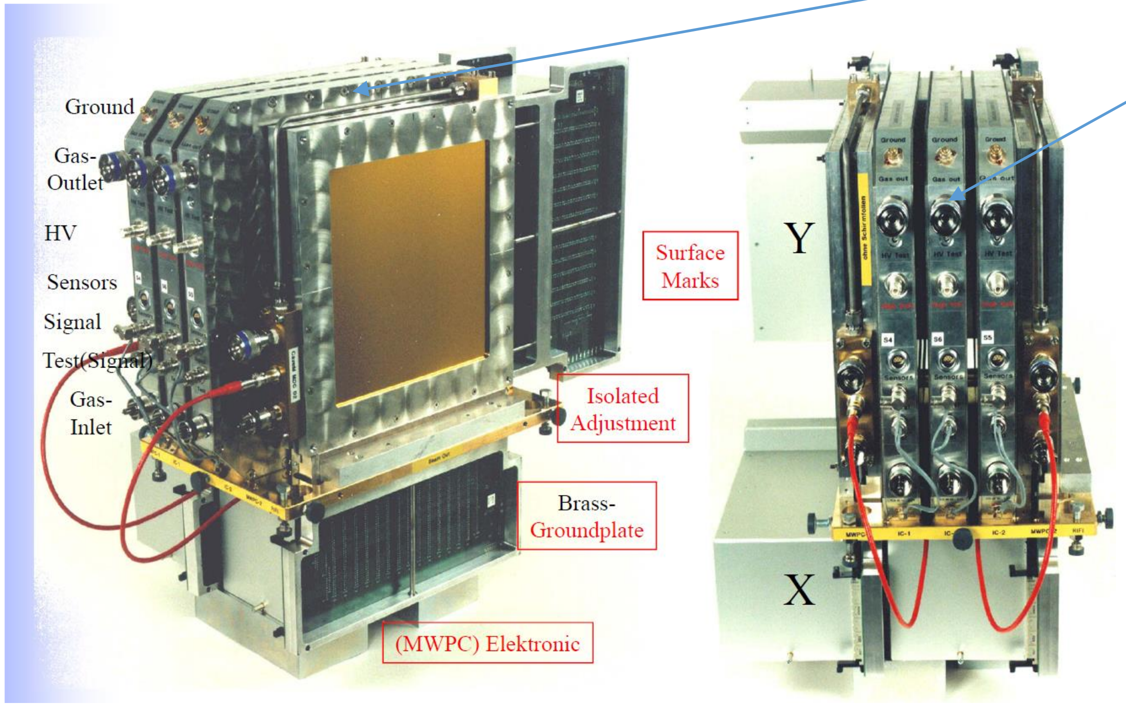
Scanned C12 beam at HIT



Existing Instrumentation for beam monitoring and dosimetry at GSI: Presentation and hands-on

Beam monitoring for scanning

Parallel plate ionisation chambers

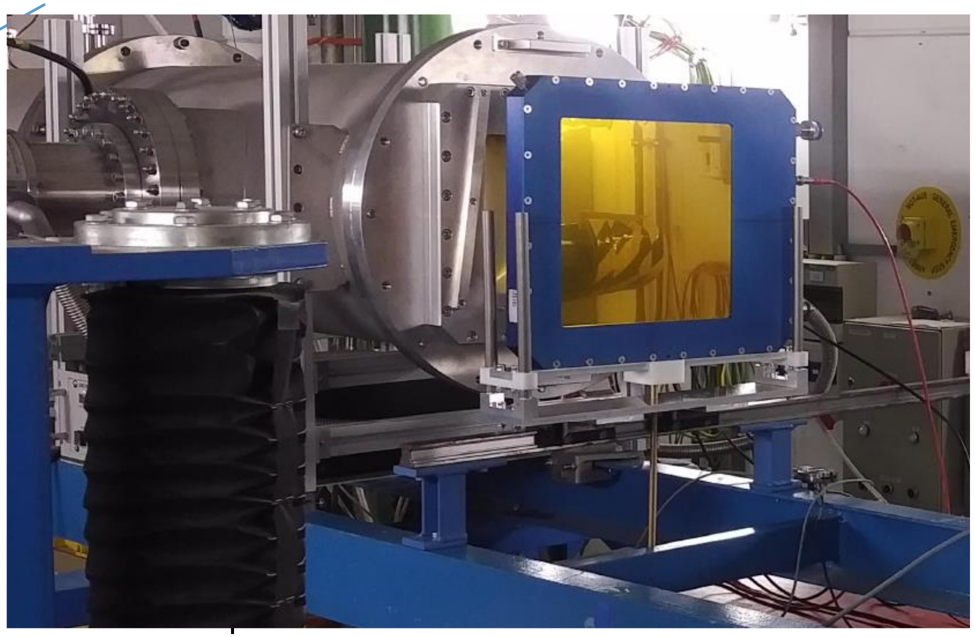


Therapy beam monitor unit

3 x parallel plate ionisation chambers (integral beam intensity)

2 x position sensítive wire proportions chamber

MWPCs currently not available
Readout electronic is updated
For TERA08 Chip



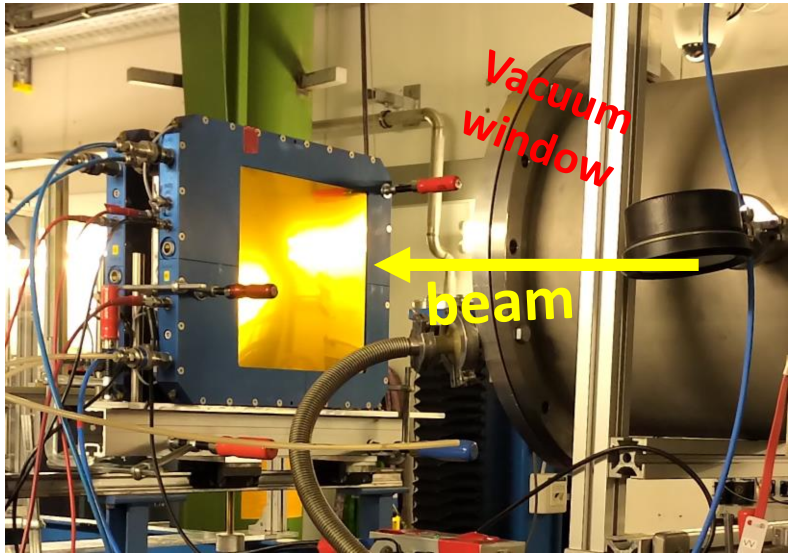
For beam monitoring in FLASH experiments

- Gas filled (He/ArCO2) for minimum recombination
- 20 x20 cm active area
- 2 x 10 mm gas gap
- up to 2000 V

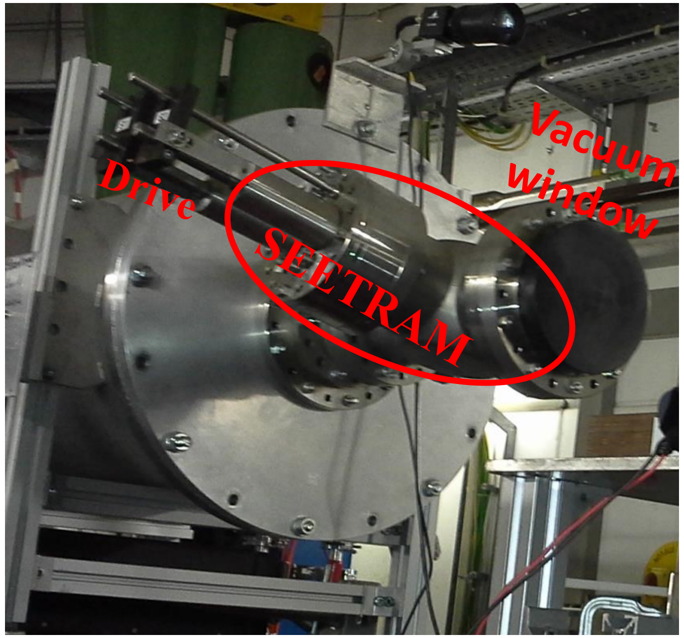
Existing Instrumentation for beam monitoring and dosimetry at GSI: Presentation and hands-on

Beam monitoring for scanning at high intensity

Parallel plate ionisation chambers, Helium/CO2 filled
up to ~5×10^{10} carbons ion/s (or equivalent dose)



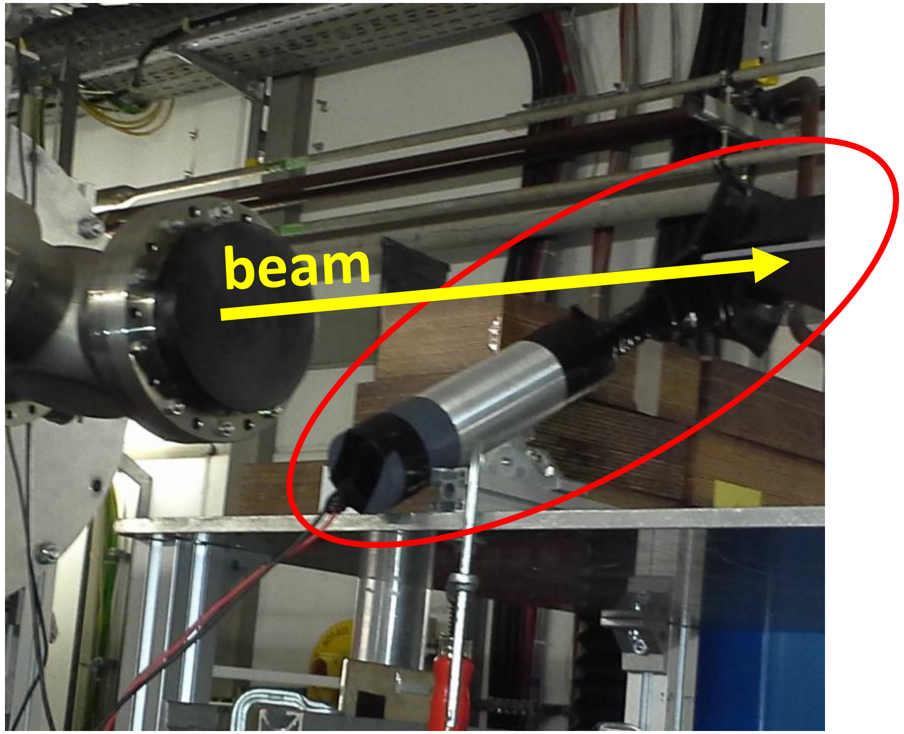
SEETRAM
SEcondary **E**lectron **TRA**nsmission **M**onitor
(highest beam intensity possible)



In-vacuum detector
Secondary electrons emitted from the middle foil are collected by the two outer foils.

Beam monitoring for scanning at low intensity

Thin (2 mm x 80 x 80 mm²) plastic scintillator with PMT

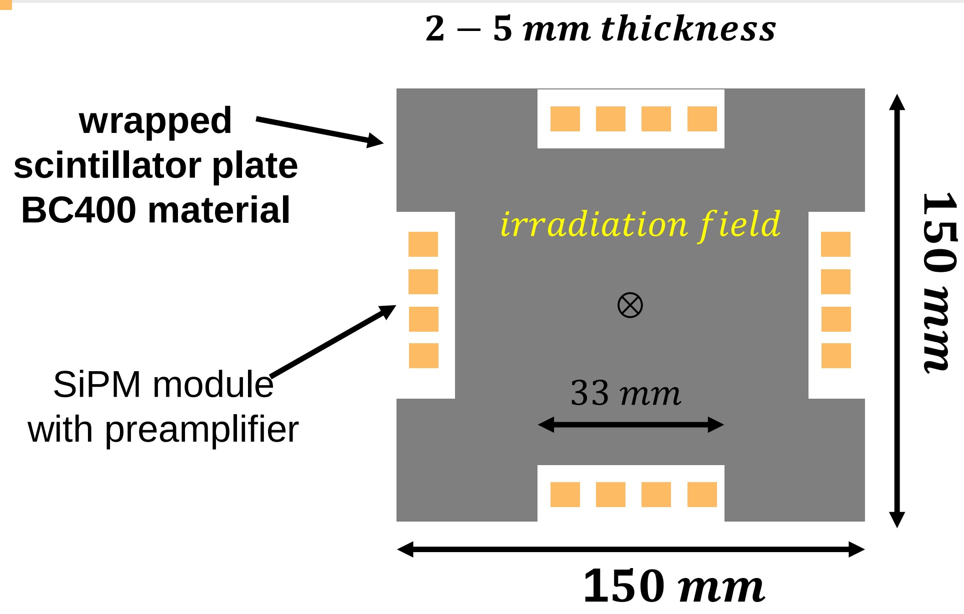


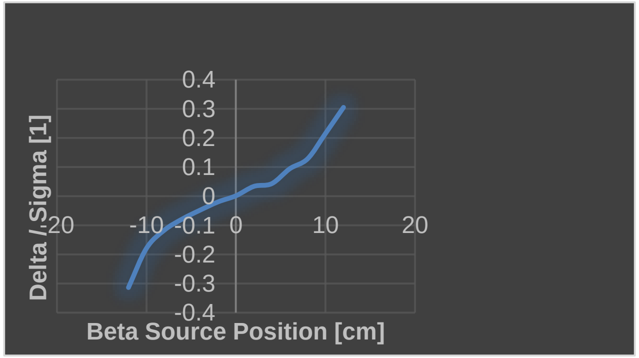
Works well for counting particles for

- Fixed pencil beams
- small field scanning < 60 x 60 mm

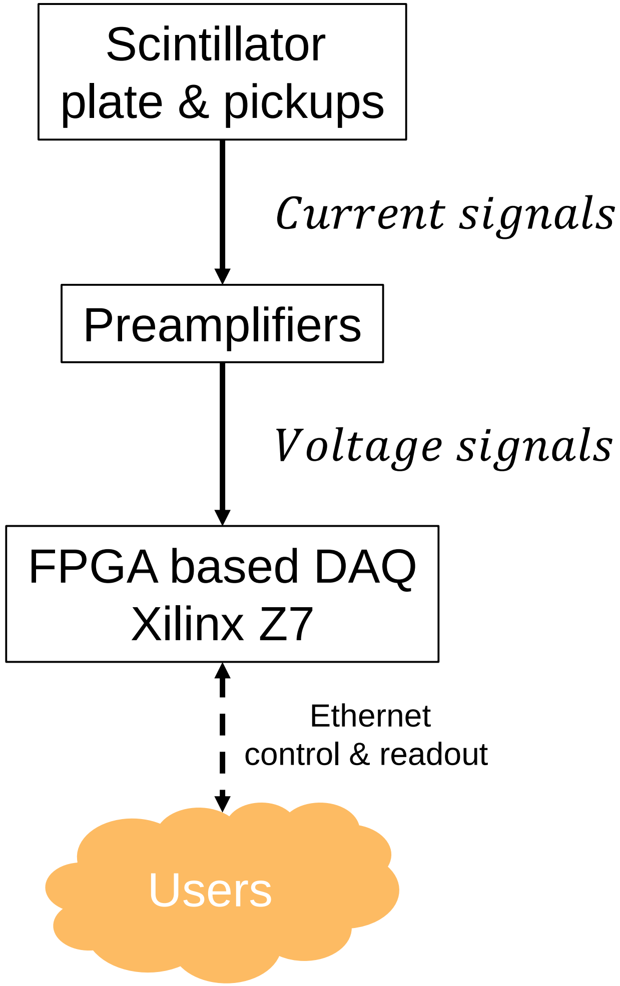
up to 10^6 ions/s

New project:
Development of a Scintillator based Detector for **Particle counting** and Beam Position monitoring

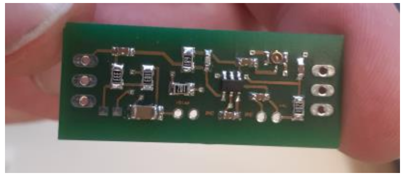


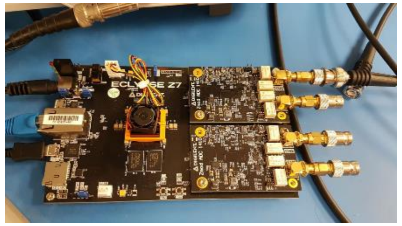


$$x_{measure} \propto \frac{U_{left} - U_{right}}{U_{left} + U_{right}} = \frac{\Delta_x}{\Sigma_x}$$

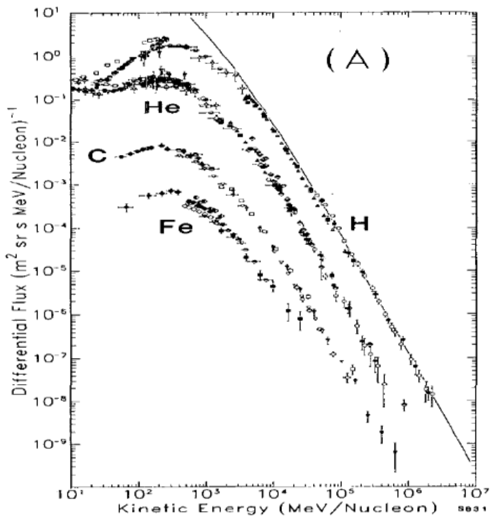


hexagonal test scintil.



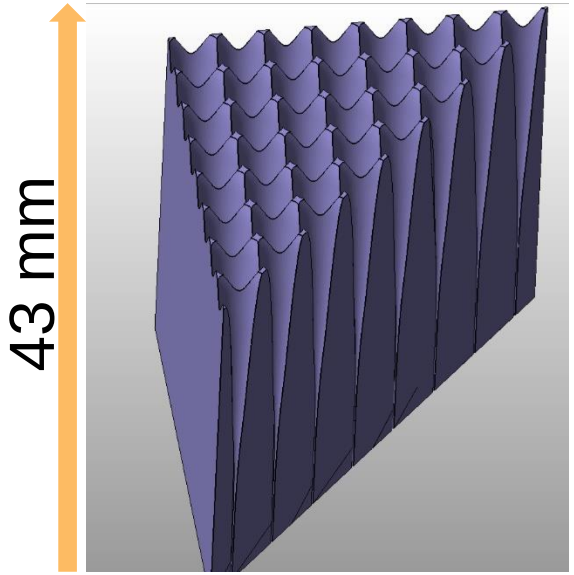


GCR simulation

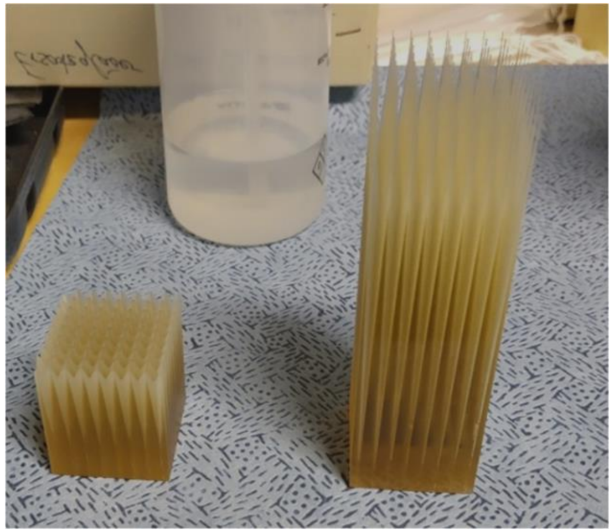


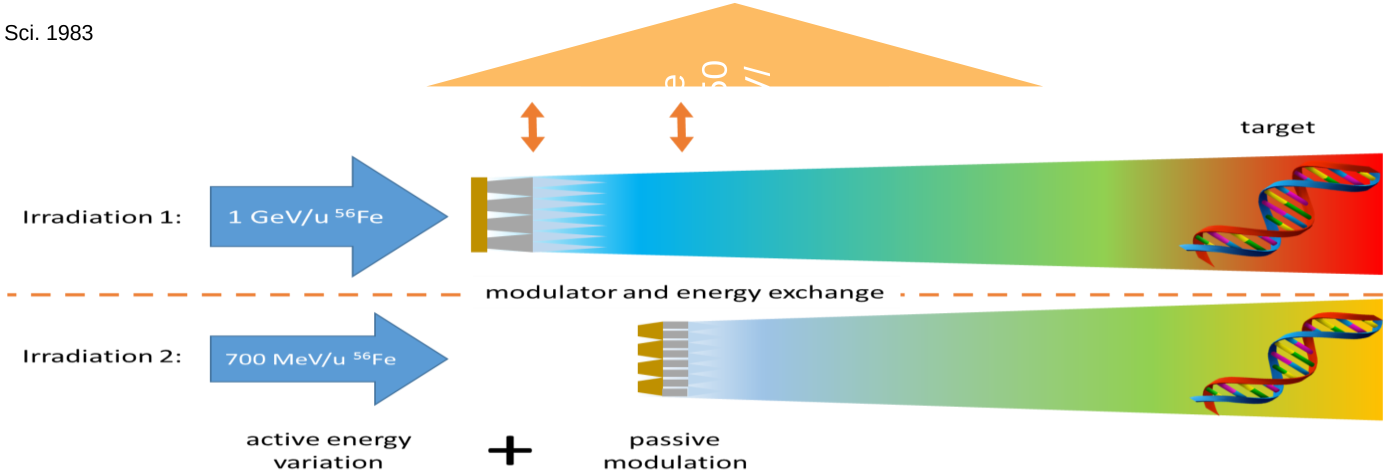
Simpson et al., Ann. Rev. Nucl. Part. Sci. 1983

Optimize



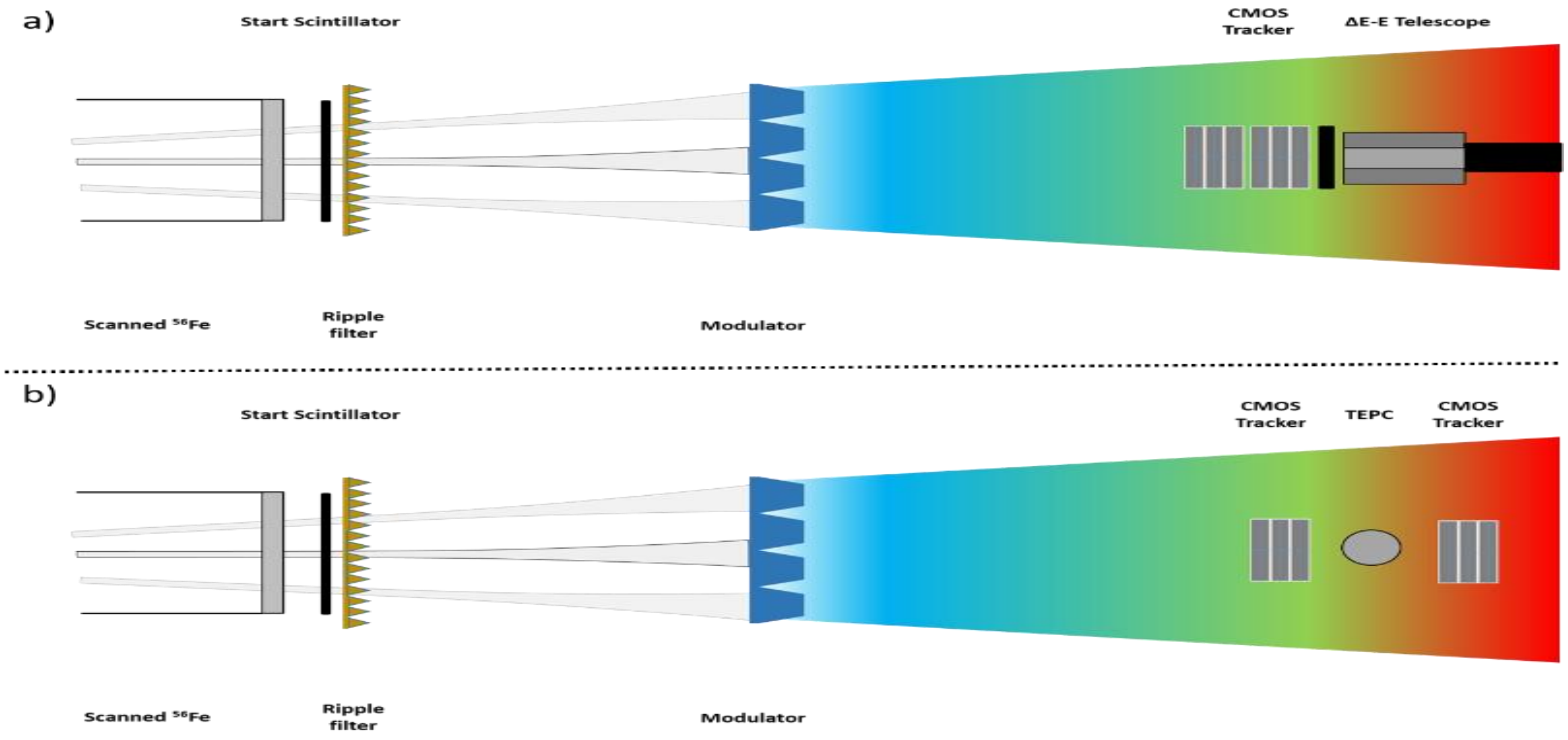
Produce





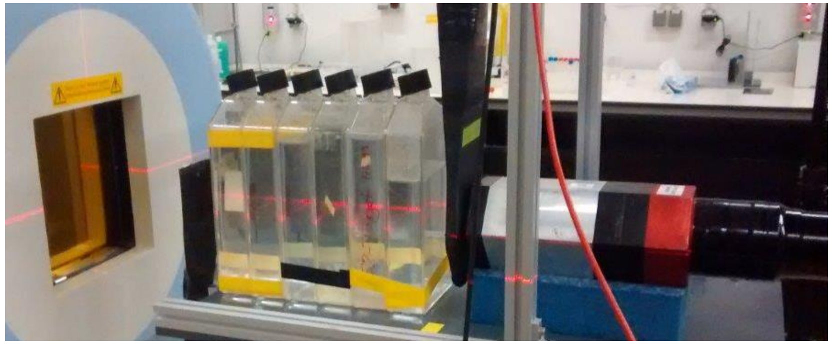
GCR simulator

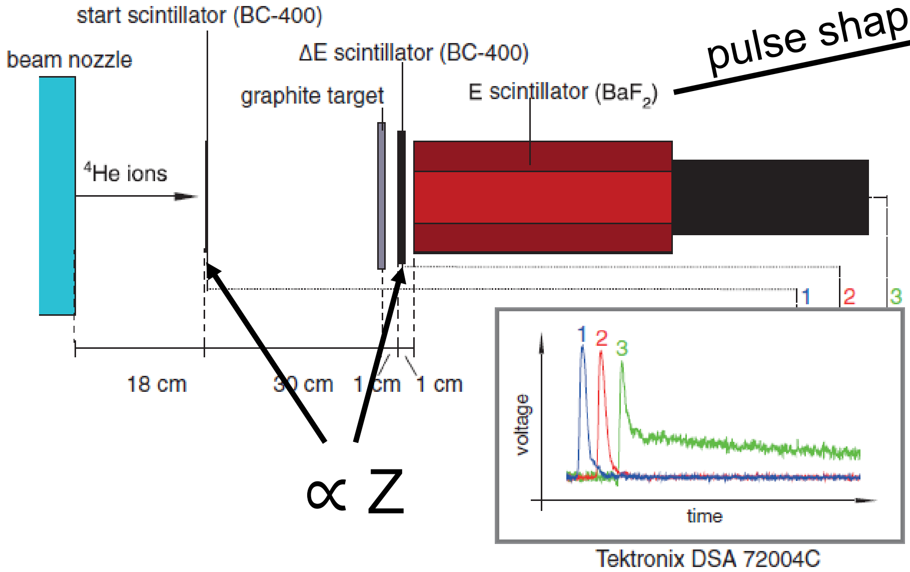
- Validation



GCR simulator

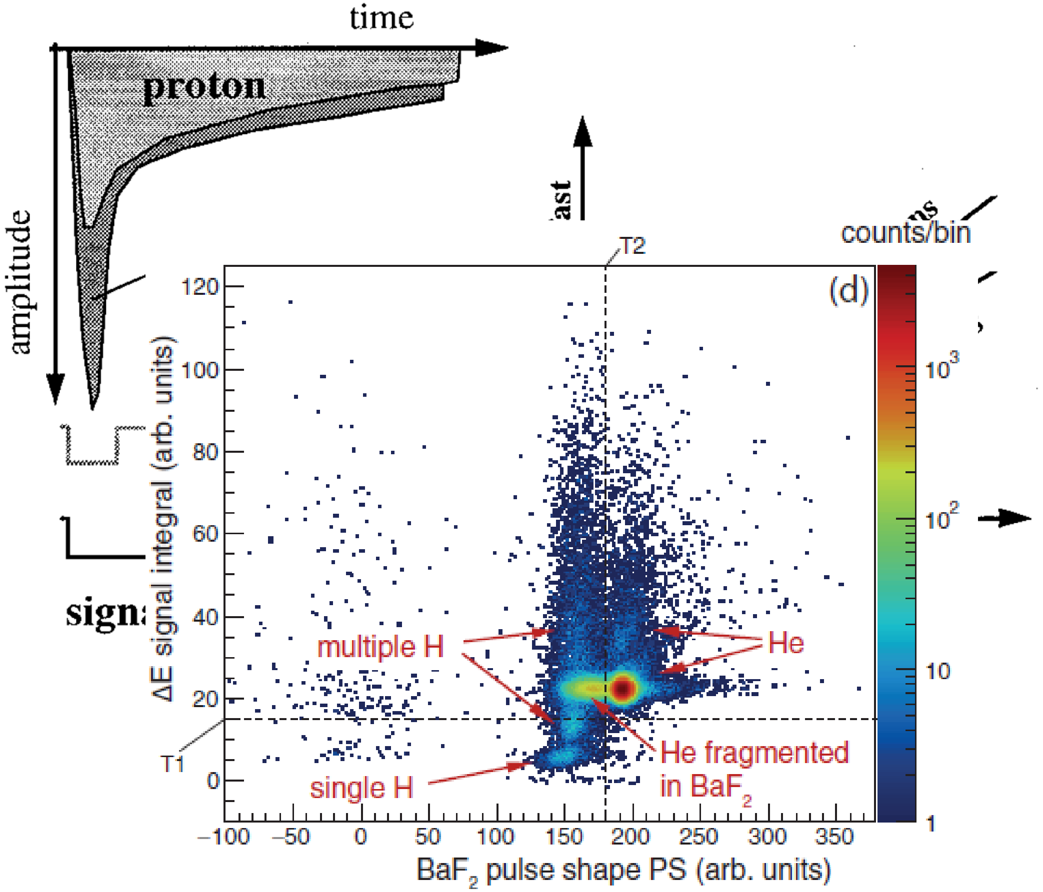
- ΔE / E





pulse shape analysis

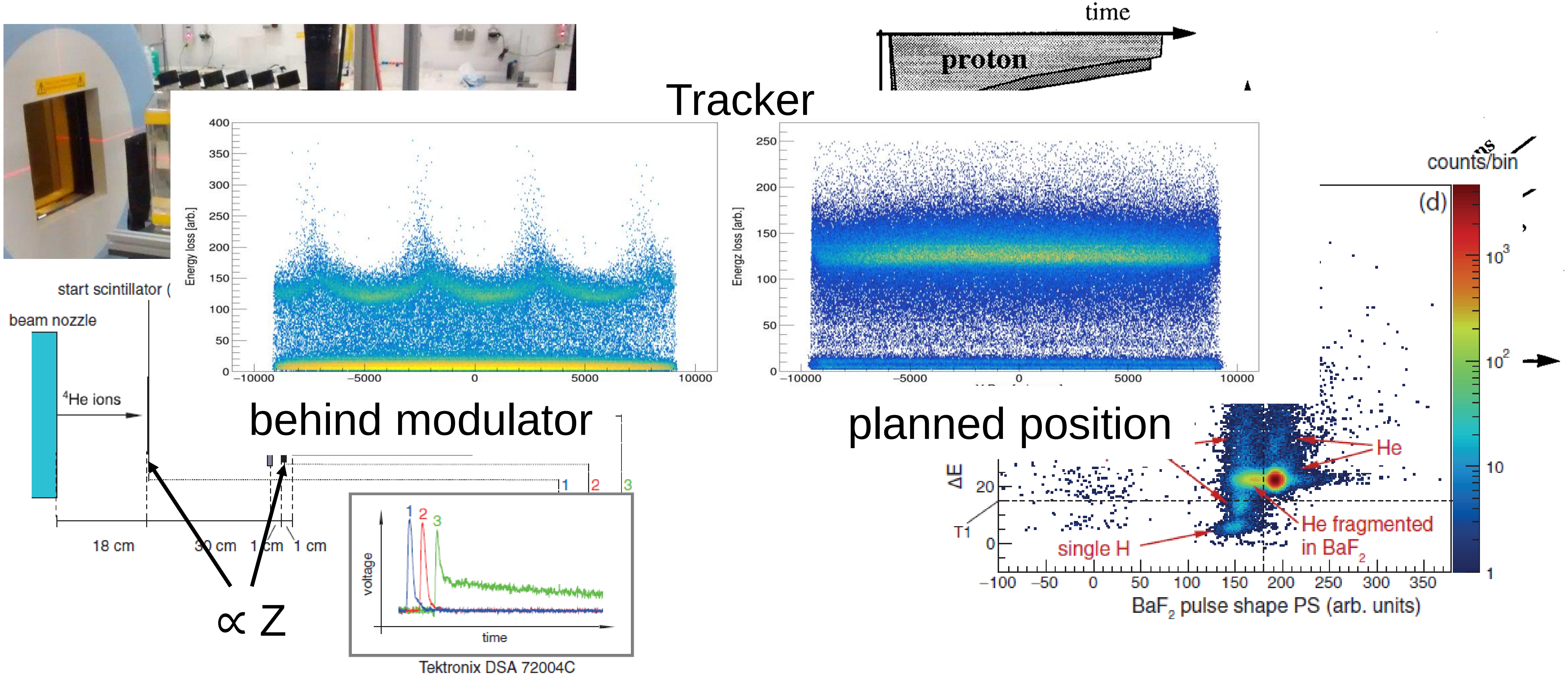
Suffers if event multiplicity is high!



GCR simulator

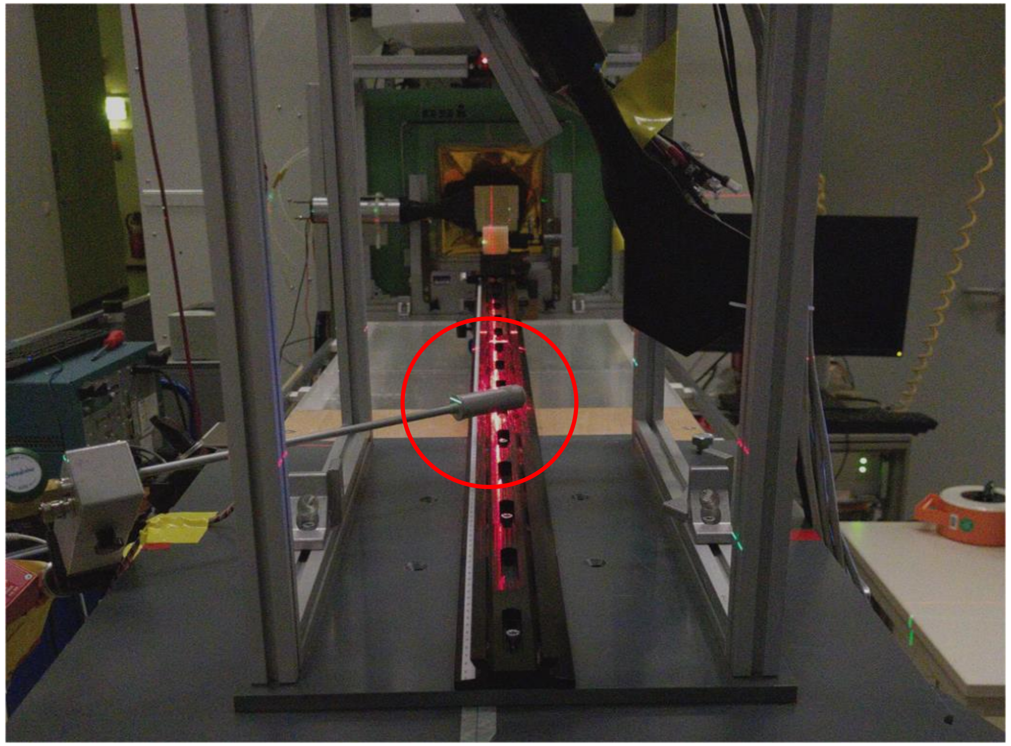
- ΔE / E

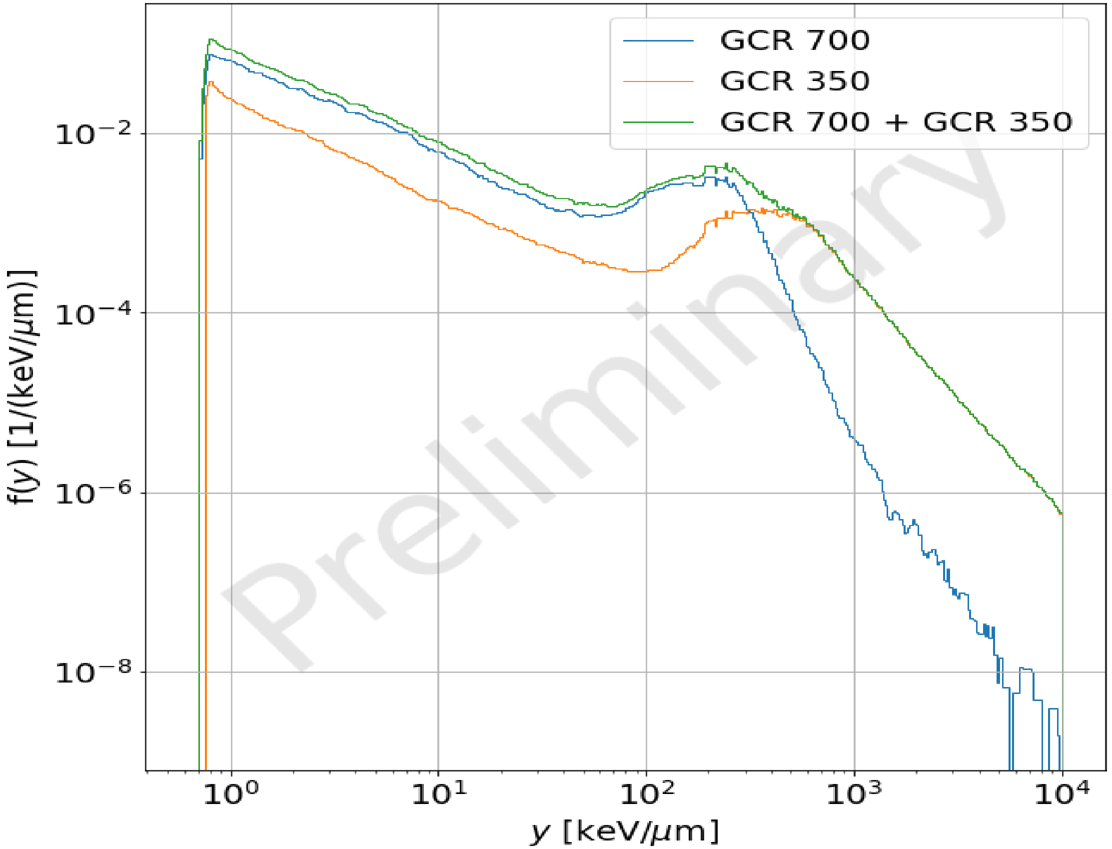
Suffers if event multiplicity is high!



GCR simulator

- Micro dosimetry (TEPC)





First Discussion: How to make CERN and GSI dosimetry comparable?

Beam parameters at GSI and CERN

	GSI	comments		CERN *[2]	comments
Energies	80-1000 MeV/u	Typically 2-3 energies		600- 5000 MeV/u*[2] Actually applied : 1000, 750, 650 MeV/u	Will be improved to 70 – 8000 MeV/u
Ions	H to U	typically C, Fe, U *[1]		Pb	
Intensity range Dose rate	500 – 10^9 per spill 1 Gy/s for 10^9 C12	Depends (a bit) on the ion species		≈10^9 ions per spill ??	
Extraction	Slow 1-10 s (quadrupole resonance)	Optional slow RF-KO (1 – 10 s), Fast kick out extraction (<1µs)			
Spill length	0.2 – 10s			200 – 400 ms	
Spill pause	< 2s	Variable duty cycle		2 spills every 45 seconds	
Delivery	Scanning	Arbitrary shapes		Static beam position	Beam shaping with collimators and octupoles envisioned
Max area	Up to 20 x 20 cm^2	< 5 x 5 cm^2 for uranium		Gaussian 10x10cm^2	Will be increased to Rectangular 20x20cm^2
Uniformity	Better than ±5%			Trade-off between beam size and homogeneity	Will be improved to ±10%

*[1] additional ions like protons, helium might be available

*[2] CERN data taken from the HEARTS Proposal document

HEARTS

First Discussion:

How to make CERN and GSI dosimetry comparable?

- **Selection of 1 or 2 certain irradiation cases** (e.g. Fe-56 1 GeV/u squared field , 10x10 cm^2)

- **Selection of the dosimetry detector setup (must be applicable at both facilities)**

➔ **Conduction of the test at both facilities (CERN & GSI)**

Define a protocol (setup and test case) for GSI / CERN

1.) High intens scenario

2.) Low intens scenario

Note:

For raster scanning the monitor calibration is easier than for a broad beam.
Even if we enlarge the field, the monitor calibration remains the same.
Actually, for scanning we can enlarge the field in very well defined way.